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Science Focus

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VISITS THE EDGE OF TIME

Inside the world's
MOST EXTREME LABS

First image of the
MILKY WAY'S BLACK HOLE

RISE OF THE MAMMALS

How our ancestors flourished in the face of an apocalypse

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If you were swallowed whole by a very large animal, how long would you remain alive for and what would you die of? →p79

FROM THE EDITOR

This month you might notice we've made some changes. Nothing dramatic, just a touch of evolution. Our goal, as always, is to try and give you more of what you love. So, for a start, we've brought in some new columnists, who we hope will provide fresh insight into your favourite subjects. This month, astrophysicist Dr Katie Mack talks about time travel, psychologist Dr Julia Shaw digs into research about sexuality, and technologist Dr Kate Darling explains why we've been getting artificial intelligence all wrong. Next month they'll be joined by Dr Radha Modgil, who'll separate facts from fads in the world of health, medicine and wellness. You'll find these new articles in the *Discoveries* section starting from p30 onwards. You might also notice we've given the rest of *Discoveries* a refresh and spruced up our tech coverage in *Innovations*. As ever, do let us know what you think about the changes via email (**reply@sciencefocus.com**).

As for the main event, this issue we're looking at the new story of how our tiny, scurrying ancestors inherited the Earth after an asteroid struck the planet. I always thought it was our intelligence – our big brains – that helped us outlast the dinosaurs, but as ever, it turns out the story is more interesting and a little more complicated than that. Over on p70, palaeontologist Dr Steve Brusatte reveals how fossils found at dig sites around the world are refining how we see the mammals that managed to thrive on a post-apocalyptic planet.

Enjoy the issue!

Daniel Bennett, Editor

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CONTRIBUTORS

DR KATIE MACK

As a theoretical astrophysicist who holds the Hawking Chair in Cosmology and Science Communication, Katie will providing a monthly digest of the most mind-blowing ideas in physics. →p30

DR JULIA SHAW

Every issue, Julia, the co-host of the *Bad People* podcast on BBC Sounds, will explore the cutting edge of psychology research. →p32

DR KATE DARLING

Kate studies human-robot interaction, tech policy and ethics at MIT's pioneering Media Lab. Every month she'll help us navigate where humans and robots might find ourselves in the future. →p34

DR STEVE BRUSATTE

A professor of palaeontology, Steve explores how new evidence is rewriting the story of how mammals came to rule the Earth. →p70

ON THE BBC THIS MONTH...

The future will be synthesised
Henry Ajder, a deep fakes expert, examines how synthetic video – where a politician or celebrity can be faked with some clever computer graphics – could affect democracy.
Available on BBC Sounds

The Truth About Tourette's
Aidy Smith has Tourette's Syndrome. In this programme he hopes to shine a light on the fact that 90 per cent of those with the condition don't actually swear. He meets people who have overcome the struggles and stigma of their condition.
BBC Radio 4
31 May, 11am
Also available on BBC Sounds

A Thorough Examination With Drs Chris And Xand: Addicted To Food
The van Tulleken twins explore our relationship with food, and ultra-processed food in particular, to find out whether it's the major driving force in the global obesity crisis.
BBC Radio 4
31 May, 3:30pm
Also available on BBC Sounds

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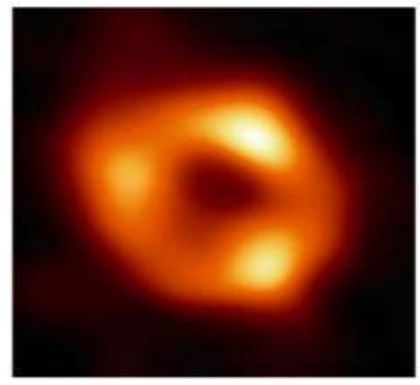

The supermassive black hole at the centre of the Milky Way, photographed for the first time.

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EYE OPENER

Finding Nemo

NOLI, ITALY

Noli is a tiny village on the Ligurian coast of Italy. Just 40 metres from the shore of this historic town, hidden beneath the surface, is a farm with its eye firmly on the future.

Nemo's Garden is a project that aims to create a new type of farming that is sustainable and eco-friendly. This comes in the form of six underwater plastic pods, also known as 'biospheres', which are the world's first underwater greenhouses.

Inside these pods, the temperature, humidity and light levels are closely monitored to ensure optimal conditions for plant growth. Plus, early studies suggest that the increased pressure inside the biospheres speeds up germination. Since the entire pod is self-contained, there's no need for pesticides.

The plants are provided with desalinated seawater. Plus, any water that evaporates condenses on the walls of the biosphere, thanks to the temperature difference between the air and the seawater outside, and is then returned to the system.

GIACOMO D'ORLANDO/SONY WORLD PHOTOGRAPHY AWARDS

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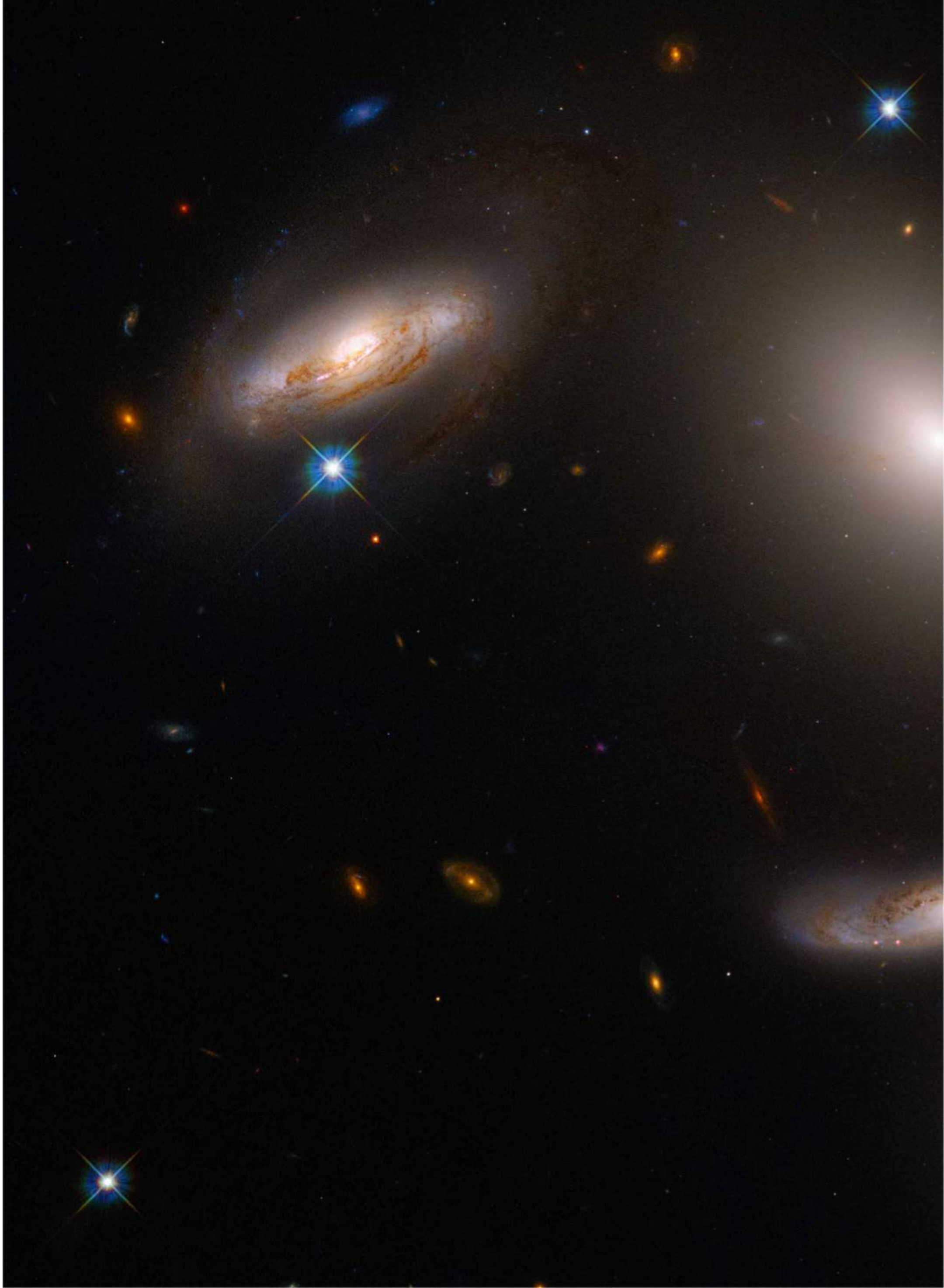

EYE OPENER

Galactic disco

HUBBLE SPACE TELESCOPE,
LOW EARTH ORBIT

This assembly of galaxies is the Hickson Compact Group 40. The prominent orange bands in the spiral galaxies are dense clouds of interstellar dust packed full of gases, and it's in these dusty regions where star formation is active.

These galaxies, pictured by the Hubble Space Telescope, are held together in a gravitational dance and they are so densely packed that they could fit in an area twice the span of our own Milky Way's disk.

Astronomers don't know for sure why these galaxies are so tightly bound, but it's possible that dark matter, a mysterious – and so far, invisible – form of matter, may play a role. When galaxies come together, dark matter can form a big cloud around the group. As the galaxies plough through this cloud, gravitational effects act like a frictional force and slow their motion. This causes the galaxies to lose energy and they fall together. Scientists estimate that in around one billion years, these galaxies will eventually collide to form one giant, elliptical galaxy.

NASA/HUBBLE SPACE TELESCOPE

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EYE OPENER

Sloth snuggles

PUERTO VIEJO DE TALAMANCA, COSTA RICA

Meet Mango and Jim. Mango, the real sloth (specifically a brown-throated, three-fingered sloth or *Bradypus variegatus*) in this cosy scene, was found on the forest floor in Costa Rica during a storm. Jim is the cuddly toy playing parent.

Mango was rescued by Dr Rebecca Cliffe of the Sloth Conservation Society. "He was only about six months old, freezing cold and making cries to try to find his mum. But she wasn't around," says Cliffe. So she warmed Mango up, gave him some food and left him in the capable hands of Jim while they waited for the storm to pass. "Jim's our surrogate sloth dad. We use a stuffed sloth because it's always good to minimise direct human contact with wild animals."

Mango was fitted with a tracking collar and released where he was found. "We're still monitoring him to this day," says Cliffe. "He's really quite lovely."

SUZI ESZTERHAS/MINDEN PICTURES

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CONVERSATION

YOUR OPINIONS ON SCIENCE, TECHNOLOGY AND *BBC SCIENCE FOCUS*

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LETTER OF THE MONTH

New fan

If you had asked me six months ago to read *BBC Science Focus* magazine, I would have laughed, politely, but with genuine hilarity at the idea! But for my father, in his late 70s, this magazine has offered him a lifeline of stimulating and challenging reading to keep his 'little grey cells' active. Having passed the magazines on to me for months, I finally picked them up and struggle to put them down! So now, as Dad and I meet for our weekly lunches, I am able to meet his enthusiasm for the latest discoveries with equal awe and wonder.

As a visual learner, I really appreciate the accessibility of the information, recently described by reader Dr Ron Barnes in April's issue as "trendy units". Please don't lose these comparative measures, think of those of us who are less academic! Not because I'm 'trendy' – heaven forbid – I'm just perfectly able to imagine the vastness of lakes and colossal entities as football pitches and elephants.

Mrs H Daniels, via email

WRITE IN AND WIN!

The writer of next issue's *Letter Of The Month* wins a **GameSir X2 Bluetooth Wireless Mobile Game Controller**. Both iOS and Android devices are supported: simply lock your phone into the controller to transform your mobile gaming into a more traditional handheld experience.

Happiness from music

In the April issue, one article stated that listening to music can make you feel happy (p34), whereas the following article (p36) said that a fabric is being researched that is so sensitive that it could be used for hearing. Hearing aids just amplify sounds and tones, making some music, especially classical, so awful as to make it not worth listening to. Hopefully this new fabric – by using an entirely different approach to loss of hearing – will give those with this disability a better alternative.

Dr Roger Webber, via email

Treasures on the Moon

I was surprised to read in your article 'The race for the Moon' (April, p52) that the metals known as rare earths are so-called because of their scarcity, especially given that a 2014 BBC article was headlined 'Rare earths: neither rare nor earths'. This kind of sloppy and unchecked reporting debases the whole concept of what should be a reliable review of scientific activity.

David Scott, Isle of Man

Could a new fabric work better than a hearing aid?

"WITH NO HINT OF HYPERBOLE, WHAT HAPPENED 66 MILLION YEARS AGO WAS PROBABLY THE WORST SINGLE DAY IN THE HISTORY OF OUR PLANET"

PROF STEVE BRUSATTE, P70

Tabby's Star has unusual fluctuations in brightness

GETTY IMAGES X2, NASA/JPL-CALTECH, ALAMY

Although fairly abundant, it's getting hold of rare earth metals that is tricky. In many ores, concentration levels of rare earths are so low, and so unevenly distributed throughout the crust, that to extract and process them is expensive, time-consuming and damaging to the environment. Once processed, only tiny amounts are needed. So, as you quite correctly pointed out, the BBC News article from 2014 is correct, and the term 'rare earth' is somewhat of a misnomer, although they are scarce in pure form and the name arises from the rarity of the minerals from which they were isolated.
Holly Spanner, staff writer

Star or sphere?

In your article about the signs of alien life (February, p52), your author made a mistake. Tabby's Star dims due to an uneven ring of dust orbiting the star, not due to dust in our Solar System, as was stated in the article. Excess dimming in ultraviolet (UV) compared to infrared (IR) suggests that dust is responsible (fine dust preferentially blocks UV over IR).

I've been following developments on Tabby's Star, as for a while it looked like the most likely candidate for a partial Dyson sphere or other large structure in orbit around the star. Plus, as an F-type main sequence star, it is a prime candidate for having developed a stable set of planets and an alien civilisation.
Michael Wehner, Cave Creek, Arizona

You are correct. The most likely location of dust responsible for the dimming of Tabby's Star is in orbit around the star itself. It is also true that it is difficult to explain all the details of the complex pattern of stellar dimming with any dust model so far proposed. The instinct of all astronomers, however, is to exhaust all possible natural explanations for an anomaly before accepting an ET explanation.
Marcus Chown, *BBC Science Focus* contributor

Oops!

Well, this is embarrassing. A few of you noticed that in the April issue, one of our *Eye Openers* said that blue light has a longer wavelength than red and orange light. This should have read as: "Sunlight is scattered by molecules in the atmosphere, and short-wavelength blue light is scattered most strongly. When there is dust in the air, there's more scattering of blue light, which means that more of the longer-wavelength red and orange light makes it through."

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“Whether directly or indirectly, we’re all in some way benefiting from corals”

Natalie Levy on corals **p26**

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CubeSats are frequently deployed to low-Earth orbit, but some scientists are concerned they’ll disrupt ground-based astronomy **p23**

SUPERMASSIVE BLACK HOLE AT THE CENTRE OF THE MILKY WAY SEEN FOR THE FIRST TIME

The Event Horizon Telescope is back with another stunning image of a supermassive black hole, but this time it's the one in our Galaxy

Astronomers at the Event Horizon Telescope (EHT) have unveiled the first-ever image of the supermassive black hole that lies at the heart of our Galaxy.

Known as Sagittarius A* (Sgr A*), the cosmic giant is four million times the mass of the Sun and is found at the centre of the Milky Way, more than 26,000 light-years away from Earth.

The remarkable image took five years to produce and comes three years after the EHT released the first image of M87*, a black hole 1,000 times more massive than Sgr A* found at the centre of the galaxy M87 around 54 million light-years from Earth.

Now that they have images of two supermassive black holes, the researchers will be able to study the differences and similarities between them.

There will be new data to test theories of how gas behaves around supermassive black holes. This process is not yet fully understood, but is thought to play a key role in shaping the formation and evolution of galaxies.

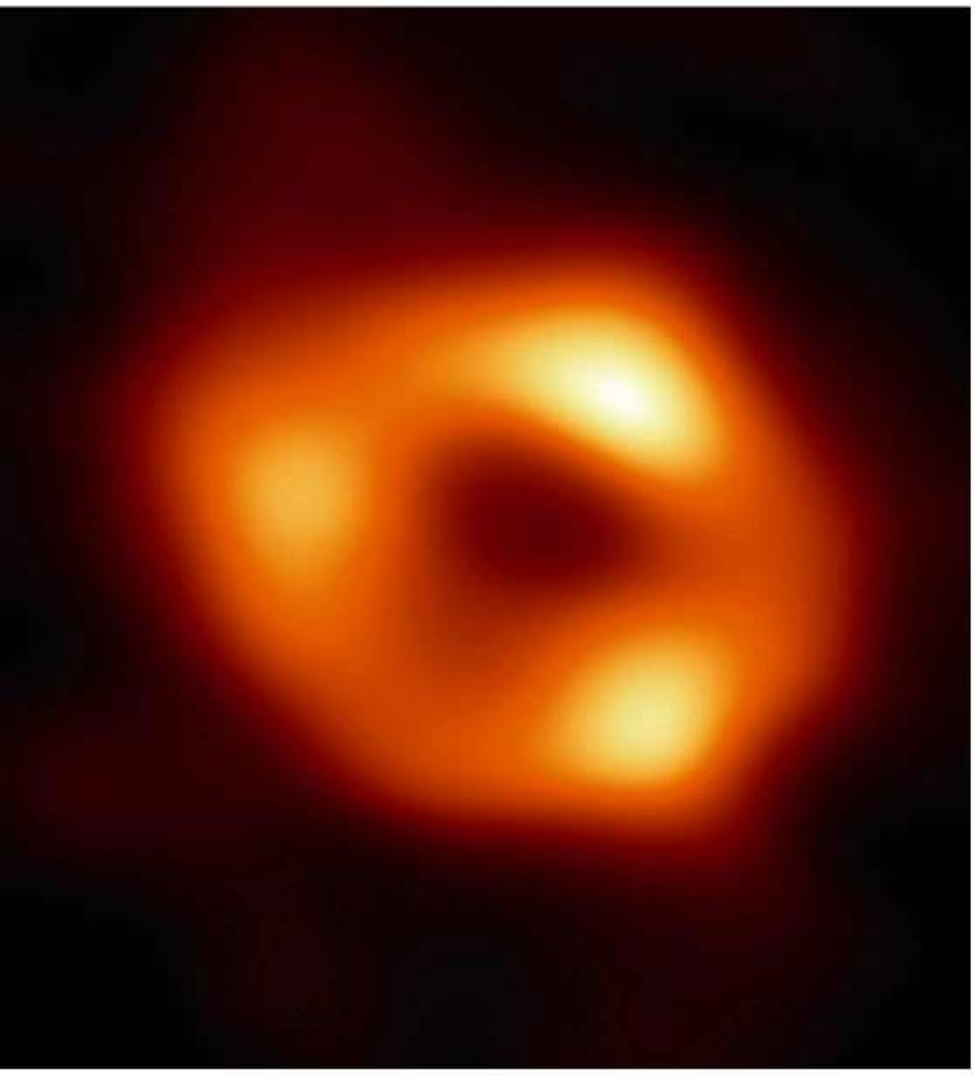
"We have images for two black holes – one at the large end and one at the small end of supermassive black holes in the Universe – so we can go a lot further in testing how gravity behaves in these extreme environments," said EHT scientist Keiichi Asada, from the Institute of Astronomy and Astrophysics, Academia Sinica, Taipei.

Technically, you can't take a photo of a black hole, as no light is able to escape it. The glowing orange ring in the photo shows the matter surrounding Sgr A*, with the 'shadow' in the centre being the black hole itself.

The incredibly strong gravitational pull of a black hole drags any nearby gas and dust into orbit around

The centre of the Milky Way lies in the direction of the rich star clouds in the Sagittarius constellation (above). And at the centre sits Sagittarius A*, the black hole that's been imaged for the first time (above right)

ESO/DIGITIZED SKY SURVEY/DAVIDE DE MARTIN/S GUISARD, EHT COLLABORATION, ESO/M KORNMESSER



“The remarkable image took five years to produce and comes three years after the first image of M87*”

it. As this material swirls inwards at nearly the speed of light, it’s heated by friction and emits energy in the form of radio waves that the EHT can detect. The researchers then use supercomputers to analyse the data it collects and create the images.

“We were stunned by how well the size of the ring agreed with predictions from Einstein’s Theory of General Relativity,” said EHT project scientist Geoffrey Bower, from the Institute of Astronomy and Astrophysics, Academia Sinica, Taipei.

“These unprecedented observations have greatly improved our understanding of what happens at the centre of our Galaxy, and offer new insights on how these giant black holes interact with their surroundings.”

The EHT is currently undergoing a series of upgrades to enable it to capture movies of black holes.

HOW DOES THE EVENT HORIZON TELESCOPE WORK?

The Event Horizon Telescope (EHT) is often referred to as an ‘Earth-sized telescope’ and as a ‘virtual telescope’. In astronomy, the bigger the telescope, the better. An amateur’s telescope with a 60mm lens will show you a decent view of the Moon’s surface or even Jupiter and Saturn, whereas the Hubble Space Telescope’s 2.4m mirror produces stunning images of nebulae and galaxies. Meanwhile, the primary mirror of the upcoming Earth-based Extremely Large Telescope is 39m across, allowing scientists to study the planets around distant stars.

But by linking together 11 telescopes around the world, the EHT can effectively create one incredibly powerful virtual telescope with a mirror the size of Earth itself.

“While Earth is rotating, all telescopes observe the same astronomical object for several hours,” says Thomas P Krichbaum at the press conference at European Southern Observatory headquarters near Munich.

“At each telescope, the data [radio waves] are recorded on hard disks and time-tagged by precise atomic clocks. The data are shipped to processing centres where they are combined in supercomputers.

“After a number of quite complex data analysis steps, this results in the high-resolution image of the radio source.”

The images the EHT is capable of producing are the interstellar equivalent of someone sitting in a beer garden in Munich, and being able to make out the bubbles in a beer glass in New York.

The sites of the telescopes that combine their ‘views’ to form the Event Horizon Telescope

HEALTH

HEPATITIS IN CHILDREN: WHAT WE KNOW ABOUT THE SURGE IN LIVER DISEASE CASES

No, it's not caused by COVID-19 vaccines, as some social media posts have suggested

The UK Health Security Agency (UKHSA) is looking into 145 cases of hepatitis in children in the UK, 10 of whom have required a liver transplant. At the time of writing, 228 probable hepatitis cases from 20 countries around the globe have been reported by the World Health Organization (WHO), and there has been one death attributed to child hepatitis since the rise was reported on 5 April.

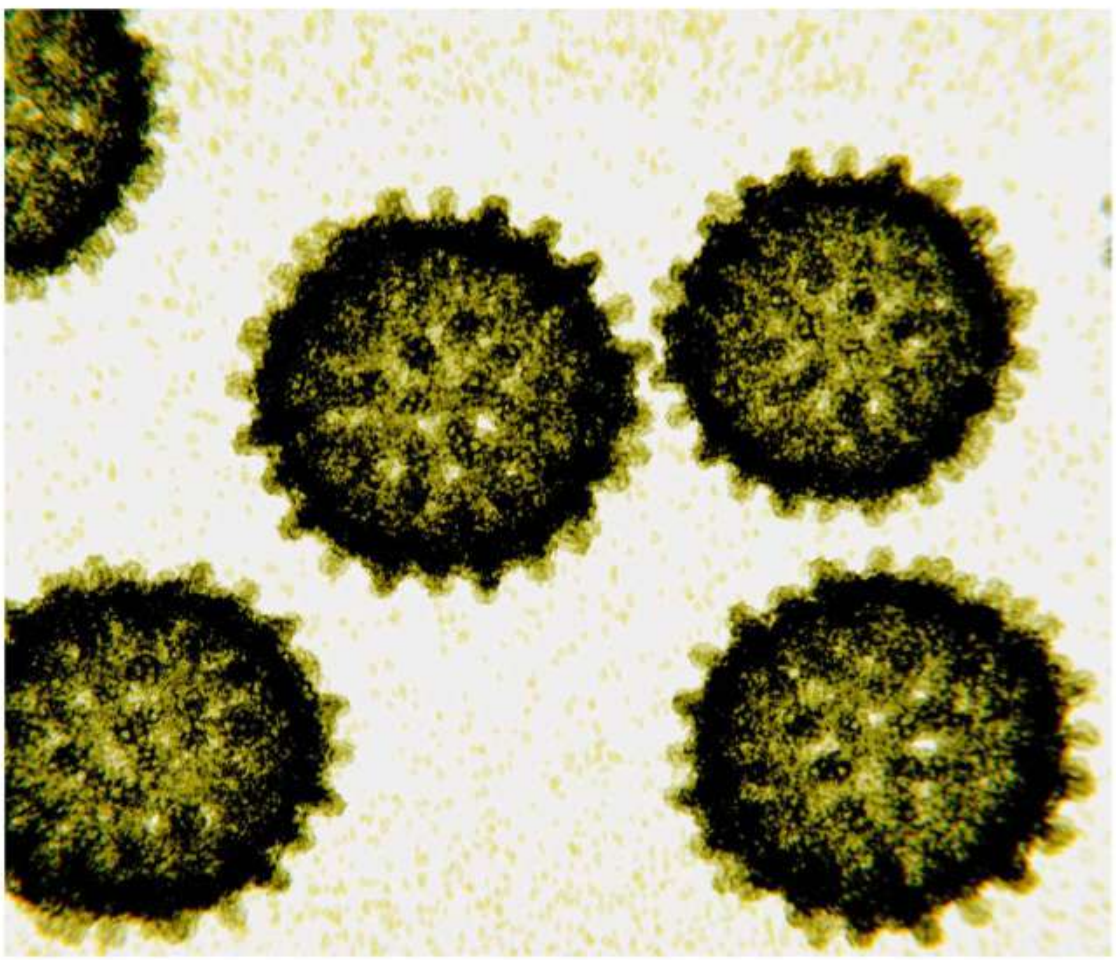
Scientists do not yet know the cause of this surge in cases of child hepatitis – an illness that sees the liver inflamed and/or injured, which can cause gastrointestinal symptoms like diarrhoea and vomiting. In cases of acute, short-term hepatitis, the inflammation usually resolves itself quickly, particularly in children. And it's also not uncommon for someone to have mild hepatitis without ever recognising any symptoms.

However, the cases currently under investigation are severe, requiring hospitalisation, treatment and, in 7.5 per cent of cases, a liver transplant.

"The liver is a tremendous organ. It's our biggest internal organ and it's the only one that has the ability to grow back," said Dr Zania Stamataki, a liver immunologist based at the University of Birmingham.

"This is a very, very rare disease. So, as a mum, I'm not hugely concerned. But as a viral immunologist, it is raising an eyebrow, because the incidence of these cases is higher than pre-pandemic levels."

"No link between the surge and one common factor has been identified"



Hepatitis can be caused by viruses

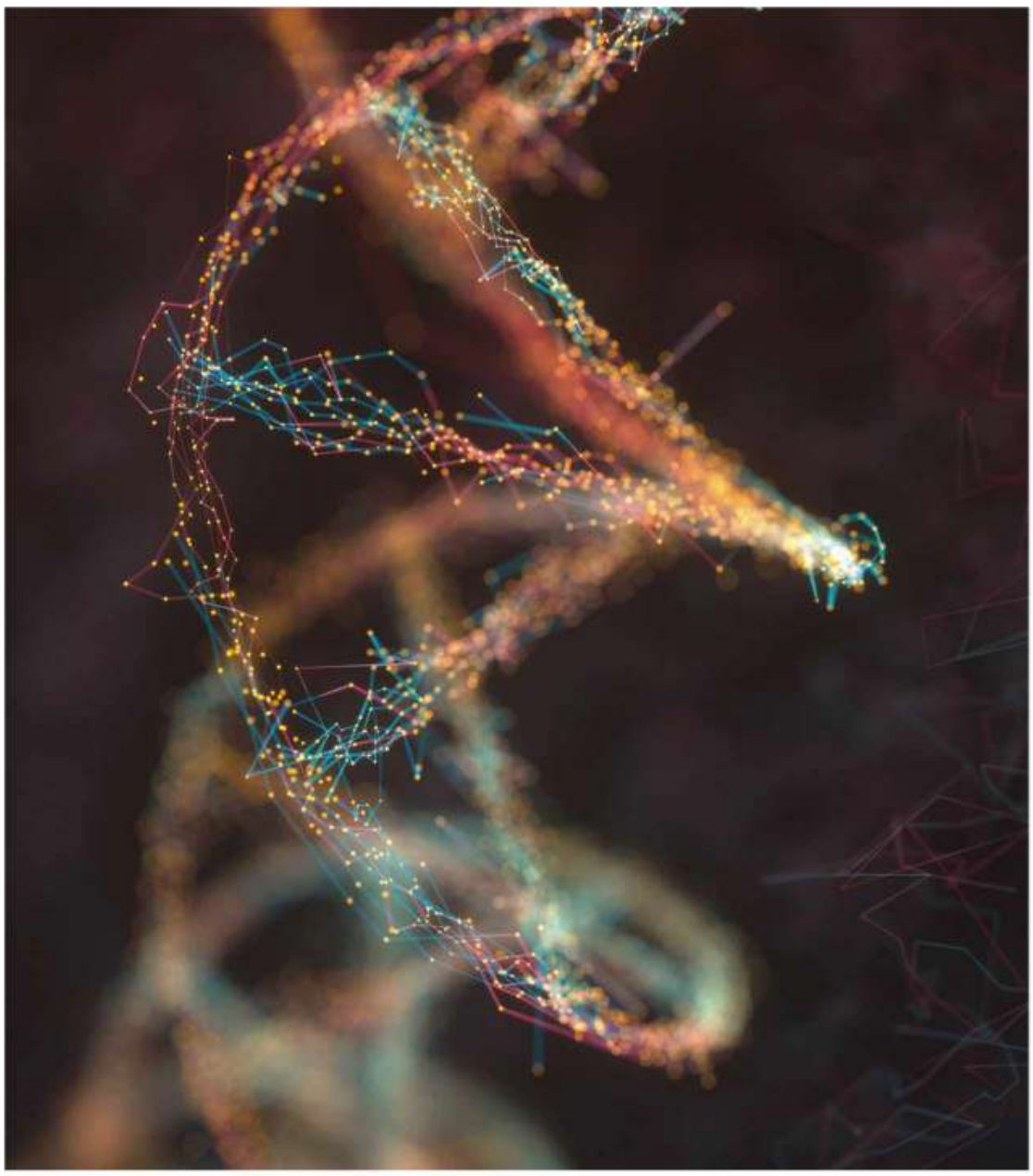
No link between the surge and one geographic area or common factor (such as particular foods or animals, travel or toxin) has been identified. But there are several hypotheses among the medical community as to the cause of the sudden rise in severe hepatitis cases. One possible cause is adenovirus infection. This common type of virus can cause illnesses such as colds, fevers, pneumonia and diarrhoea.

The UKHSA is also investigating the potential role of COVID-19 vaccinations, but the WHO reports that the majority of children with the illness have not received the vaccine. Others have suggested that the sudden rise in cases could be due to COVID-19 lockdowns, as children have not been exposed to as many viruses and infections.

"It's an interesting hypothesis," said Stamataki. "Children need viral infection over the years to build up their immunity to incoming viruses. But this doesn't explain why only a handful of those children had severe disease."

Health officials have said that 16 per cent of UK cases of child hepatitis were positive for coronavirus when they were admitted to hospital. However, as levels of COVID-19 were high in the general population at that time, it would not be unexpected for the children to test positive.

The NHS is encouraging parents to see their GP if their child has hepatitis symptoms. It recommends that any child experiencing vomiting and diarrhoea should stay home and only return to school or nursery once 48 hours have passed.



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GENETICS

QUANTUM WEIRDNESS COULD BE THE DRIVING FORCE BEHIND DNA MUTATIONS

Potentially harmful changes in genetic code may be caused by subatomic particles 'tunnelling' across the DNA helix

Genetic mutations could be caused by quantum effects, researchers from Surrey University have found. Mutations are changes in the DNA of an organism that can result from errors made during cell division, viral infections or exposure to radiation and carcinogens. They are essential to evolution as they can lead to adaptations that allow certain organisms to outcompete others in their environment, but they can also lead to disease.

Mutations can be thought of as 'spelling mistakes' in the genetic code. DNA is made up of four nucleotide bases – A, C, T and G – that under normal conditions always bond together in specific ways: A always bonds to T, for example. These bonds form the 'rungs' of the ladder that makes up DNA's iconic double-helix structure.

However, if the nature of these bonds becomes altered in some way, then the normal pairing rules break down, leading to incorrect bases becoming attached to one another and possibly giving rise to a mutation.

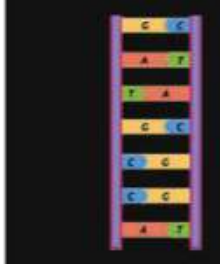
Now, the Surrey team has found that this mismatched bonding may be caused by a mysterious phenomenon known as quantum tunnelling. Tunnelling occurs when particles move through a barrier that, according to classical physics, they shouldn't be able to cross. The barrier may be a physically impassable medium, such as an insulator, or a region of high energy that the particle isn't energetic enough to overcome.

In the case of genetic mutations, researchers found that protons, subatomic particles involved in the bonding of DNA, are continuously tunnelling back and forth across the energy barrier found between the two sides of the helix.

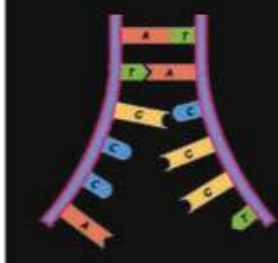
If they do this in the moments before the helix splits along its centre during the first stage of the DNA copying process, some of the protons can get caught on the wrong side. This can lead to an error in copying and, potentially, a mutation.

"Biologists would typically expect tunnelling to play a significant role only at low temperatures and in relatively simple systems," said the study's co-author Dr Marco Sacchi. "Therefore, they tended to discount quantum effects in DNA. With our study, we believe we have proved that these assumptions do not hold."

HOW DNA REPLICATES



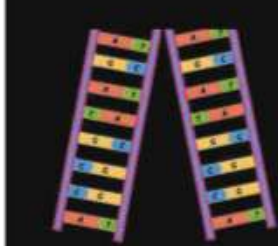
1 Portion of DNA about to undergo replication



2 The two strands separate. Here, you can see the four 'letters' of the nucleotide bases: A, C, T and G

3 The enzyme DNA polymerase reads each strand and attaches complementary bases

4 The bases are joined together. A goes with T, and C goes with G



5 Two identical strands of DNA have now been formed

Videoconferencing is a convenient way of interacting with colleagues in different locations, but it may make it harder to bounce ideas around

GETTY IMAGES X2

TECHNOLOGY

VIDEOCONFERENCING STIFLES CREATIVITY

Being tethered to a screen makes us less likely to mentally wander, and this has an impact on our creative thinking

Thanks to the pandemic, more people are or have been working from home. Multiple studies and surveys have shown that many would like to carry on doing so, even as the threat from COVID-19 fades. New research carried out in the USA, however, suggests that in-person teams tend to perform better at certain tasks than those working remotely.

Specifically, the researchers found that teams working remotely performed less well at idea generation than teams working face-to-face. When it came to the next stage of the job – selecting which of those ideas were worth pursuing – the two cohorts performed equally well.

The study involved 602 participants, who were assigned randomly to pairs. With half the pairs sitting face-to-face in one room, and half using videoconferencing software, subjects were asked to come up with novel uses for a product such as a Frisbee or bubblewrap, then after five minutes were given a minute to select the best of those ideas. All of their ideas were then passed to a team of independent judges who rated them for both creativity and practicality.

The researchers found that the in-person teams generated a greater number and wider range of ideas than the virtual teams, although when it came to their ability to pick the 'best' idea (rated by comparing the creativity and practicality scores of the ideas they chose with the scores of those picked by the judges), there was little difference between the two groups.

To make sure that the traits observed, and the conclusions drawn, weren't specific to any given population group – the original experiments were

conducted on US university campuses, and respondents skewed young and female – the tests were then replicated, with the subjects this time being some 1,490 engineers working for a large international telecoms infrastructure company. This second cohort came from five countries across Europe, the Middle East and Asia.

For this second set of tests, participants were asked not to think of hypothetical uses but to come up with new product ideas for their real-life employer – the idea here being that this would more closely replicate a real-world scenario. Using a variety of methods, including linguistic analysis and gaze-tracking, as well as testing participants' ability to recall objects seen in the test environment, the researchers found that people in the in-person group looked around the room and talked 'across' each other more, whereas those using videoconferencing software took it in turns to speak and kept their eyes on the screen. These things negatively correlated with idea generation.

The researchers concluded that this narrowing of the visual scope may lead to a narrowing of overall cognitive focus, making it harder to come up with novel, creative or off-the-wall ideas.

"When we visually focus on a screen and filter out peripheral input, this in turn prompts a narrowed cognitive focus, but creativity benefits from unfocused thinking," said Prof Melanie Brucks, co-author of the research. "In other words, when we are visually tethered to a screen, we are less likely to mentally wander."

"When we focus on a screen and filter out peripheral input, this prompts a narrowed cognitive focus"

Despite this, many employees will need to continue using videoconferencing for work – a YouGov study in late 2021 found that more than half of UK survey respondents wanted to work from home, at least some of the time. According to their results, Brucks suggests employers who have hybrid workers save the more creative, exploratory work for in-person times.

As the study found that participants who took the time to gaze around the room and look at their environment had an increased number of creative ideas, perhaps an interval for eye-wandering should be factored in to your next Teams call?

HEALTH

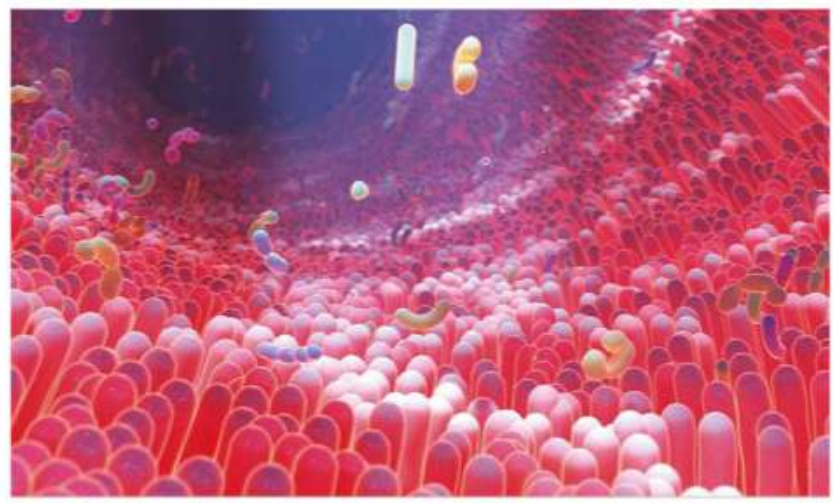
GUT MICROBES MAY INFLUENCE THE RISK AND SEVERITY OF STROKE

The discovery could lead to new methods of treating or preventing stroke

Bacteria found within the human gut may play an important role in stroke, a study carried out in Barcelona, Spain, has found.

According to the Stroke Association, stroke is a leading cause of death in the UK, with one person affected every five minutes. Of these, ischaemic strokes are the most common and occur when a blood clot blocks the flow of blood and oxygen to the brain. These clots usually build up in areas where the arteries have become narrowed by fatty deposits known as plaques.

"The influence of the gut microbiome – the trillions of bacteria and other microorganisms that live in the gut – is a modifiable risk factor associated with the risk of stroke and with post-stroke neurological outcomes. However, most research has previously been done in animal models," said lead author Dr Miquel Lledós.



Artist's impression of human gut bacteria in the large intestine

In the new study, researchers from the Sant Pau Research Institute Stroke Pharmacogenomics and Genetics Laboratory took faecal samples from 89 participants who had suffered from ischaemic strokes and compared them to samples taken from a healthy control group. They found that several types of gut bacteria were linked to an increased risk of stroke. Two others were linked to more severe symptoms in the 24 hours following a stroke. At least one other was linked to a poorer neurological recovery in the three months following a stroke.

The researchers hope that their findings can lead to the development of new treatments, which use the microbiome to prevent stroke and improve recovery.

BRAIN

STRESSED CELLS OFFER HINTS TO NEW DEMENTIA TREATMENTS

A newly discovered mechanism suggests that when stressed, neurons can eliminate the toxic protein tangles seen in Alzheimer's

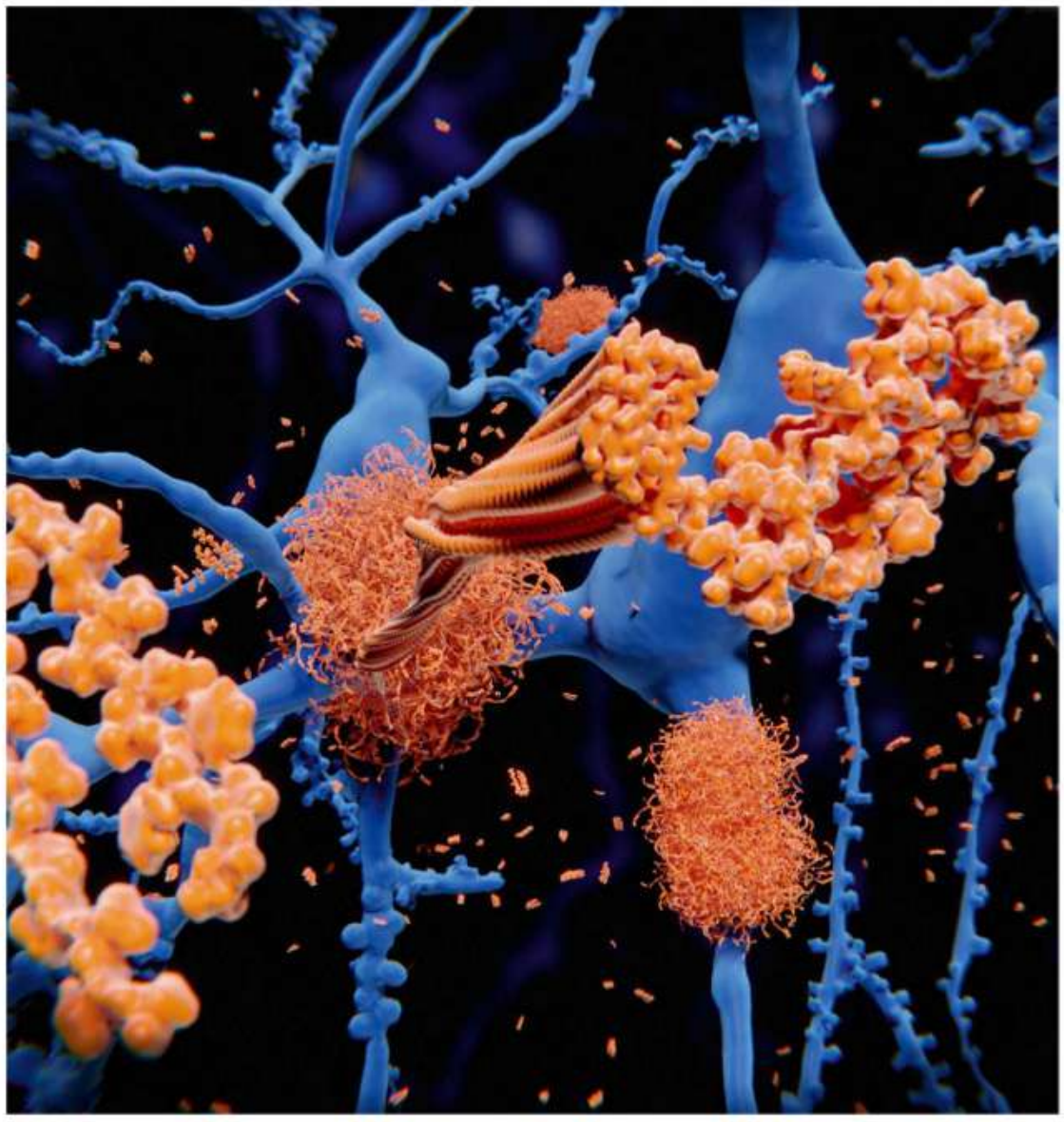


Illustration of the protein aggregates (brown) that clump together on neurons (blue) in some neurodegenerative diseases

Triggering a stress response in neurons may help to unravel the damaging tangled proteins that build up in the brains of people with neurodegenerative conditions, a study carried out at the University of Cambridge has found.

The finding could lead to innovative new treatments for conditions such as Alzheimer's and Parkinson's, if researchers are able to identify drugs that repeat the effect, they say.

Damage is often caused to the brain tissue of patients with Alzheimer's and Parkinson's, due to the accumulation of misfolded proteins that break free and clump together in the brain. It was previously believed that once these protein aggregates form, it is nearly impossible to clear them.

To make their discovery, the team focused their attention on a structure found within many cells called the endoplasmic reticulum (ER). The ER produces around one-third of a cell's proteins, allows for their movement around a cell, and can also alter them by folding.

The team initially suspected that stressing the ER by heating it to 43°C would trigger it to produce more proteins which would lead to more misfolding and greater buildups. What they found was the opposite.

"Just like when we get stressed by a heavy workload, so too can cells get 'stressed' if they're called upon to produce a large amount of proteins," said Dr Edward Avezov, a researcher at the University of Cambridge and one of the authors of the study.

"We found that stressing the cells actually eliminated the aggregation"

"We were astonished to find that stressing the cells actually eliminated the [aggregation] – not by degrading them or clearing them out, but by unravelling the aggregates, potentially allowing them to refold correctly. If we can find a way of awakening this mechanism without stressing the cells – which could cause more damage than good – then we might be able to find a way of treating some dementias," he added.

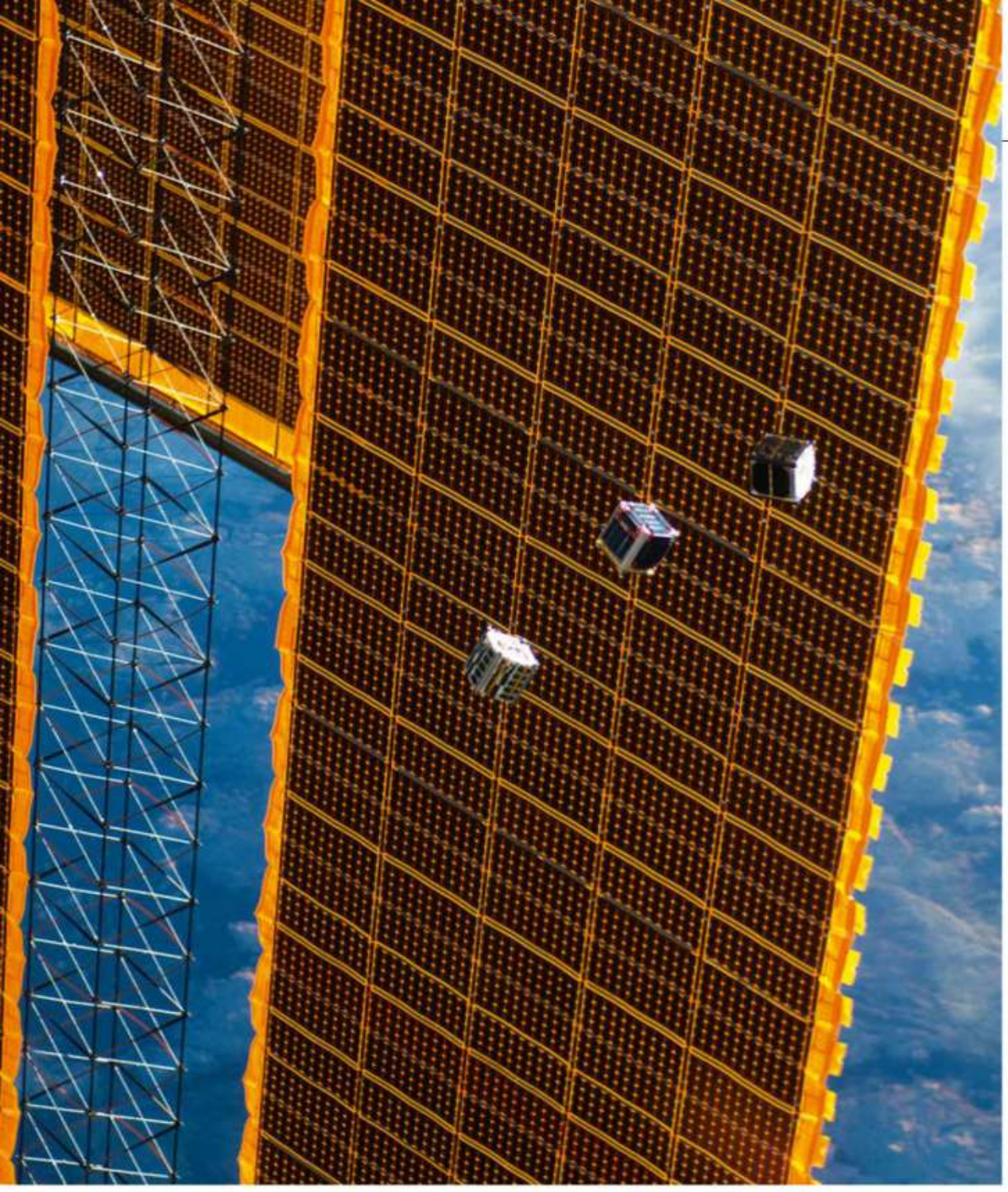
One particular compound found to aid the unravelling was a protein called HSP, which responds to increases in heat. This understanding, Avezov said, may explain why people in Scandinavian countries who regularly use saunas may be at lower risk of developing dementia.

"One possible explanation for this is that this mild stress triggers a higher activity of HSPs, helping correct tangled proteins," he said.

DEMENTIA IN THE UK

According to the Alzheimer's Society, there are currently around **900,000 people in the UK living with dementia**. It mainly affects people over the age of 65 but the likelihood of developing the disease increases significantly with age. Currently, around **1 in 14 people aged over 65** are living with dementia. This rises to **1 in 6 for people aged over 80**.

SCIENCE PHOTO LIBRARY, ALAMY X2



ASTRONOMY

STARGAZERS CALL FOR GREATER REGULATION OF SATELLITE LAUNCHES

"It's time to clean up space," say astronomers, as ever more satellites are launched into low Earth orbit

Here are three numbers for you: 2,000, 100,000 and 327,000. The first is the number of active satellites in orbit around Earth in 2018. The second is the number of satellites predicted to be there by 2030. And the third is the number of new satellites that the Rwanda Space Agency recently applied for permission to launch.

Even though the vast majority of satellite launches these days are of CubeSats – microsatellites that are very small (usually consisting of standardised units that are 10 x 10 x 10cm) – that's a huge increase. And if you're a ground-based astronomer, it presents a real problem.

Having that much hardware floating around so close to Earth makes it more difficult to see the stars. It also makes it highly likely that any excitedly reported 'new comets' will turn out to be human-made. Which is why a team of scientists from the UK, US, Canada and the Netherlands, writing in the journal *Nature Astronomy*, has called for greater regulation of satellite launches.

"We really need to get our act together," said lead author Prof Andy Lawrence, at the University of Edinburgh. "This is about recognising that the problems we see in orbit are the same as those we see when we worry about the land, the oceans and the atmosphere."

There are, of course, many regulations governing satellite launches already – so much so that the process of having a launch proposal approved by all the relevant regulatory bodies and national authorities takes years. But the rules that currently apply relate almost entirely to proposed launch dates and flight paths, so that the satellites don't crash, as well as to what frequencies they use to transmit and receive data, so that the satellites' signals don't interfere with each other.

The astronomers say that little thought is currently being given to how new launches might affect an Earth-bound view of the night sky. They also point out that satellite launches are highly carbon-intensive and polluting, and that current regulations don't take into account what's going to happen to all the satellites when they reach the end of their working lives and re-enter Earth's atmosphere. The more satellites that do this, the greater the risk posed by falling space debris, argue the researchers. "The first aircraft strike or ground casualty is only a matter of time," the article says.

"We need to see where we have regulations that we're not applying properly, and where we need new regulations," said Lawrence. "We need to knock heads together and ask, 'How do we solve this problem?'"

CubeSats of various configurations (above and right) are frequently deployed from the International Space Station

International Space Station

SPACE

'WALKING' ROBOTIC ARM POWERED UP ON INTERNATIONAL SPACE STATION

Russian cosmonauts activated the European Space Agency-designed bot during historic event that marked the 250th spacewalk carried out on the ISS

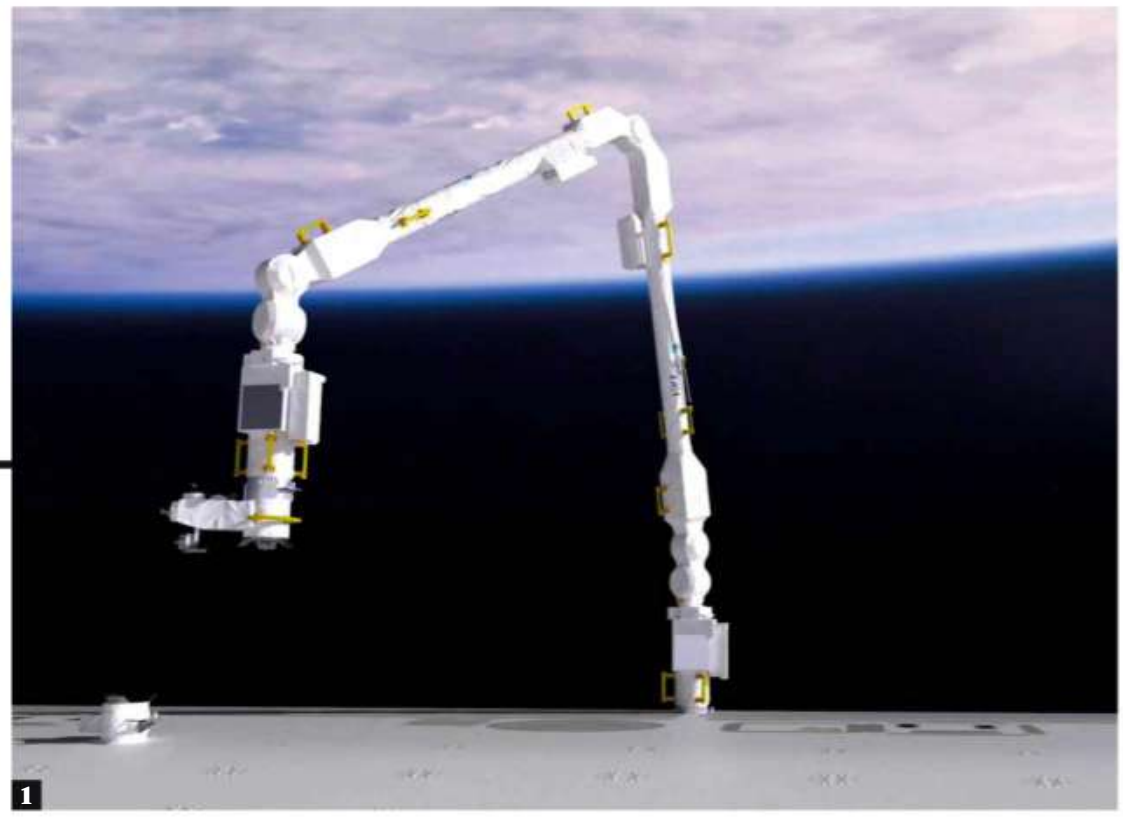
On 28 April, Russian flight engineers Oleg Artemyev and Denis Matveev successfully switched on the European Robotic Arm (ERA) during a spacewalk lasting seven hours and 42 minutes. The robot has the ability to anchor itself to the exterior of the ISS and 'walk' backwards and forwards. It will be used for maintenance and transferring payloads, freeing up cosmonauts to carry out other work. It will begin its first mission in August.

1. The ERA is able to 'walk' around the ISS by gripping one of the fixed base points found on the space station's exterior with either of its 'hands', before moving its free hand to grab on to the next basepoint using its elbow and wrist joints.

2. The robot can be controlled and programmed remotely. This image shows ESA astronaut Samantha Cristoforetti practising operating the robotic arm on a computer simulator at Moscow's Yuri Gagarin Cosmonaut Training Centre.

3. The arm is designed to transfer payloads in and out of the ISS and to inspect the exterior of the orbiting habitat using its four infrared cameras.

4. The 11-metre ERA weighs 630kg on Earth but can handle objects of up to 8,000kg in orbit. Each of its limbs are made from five-metre lengths of ultralight carbon fibre.



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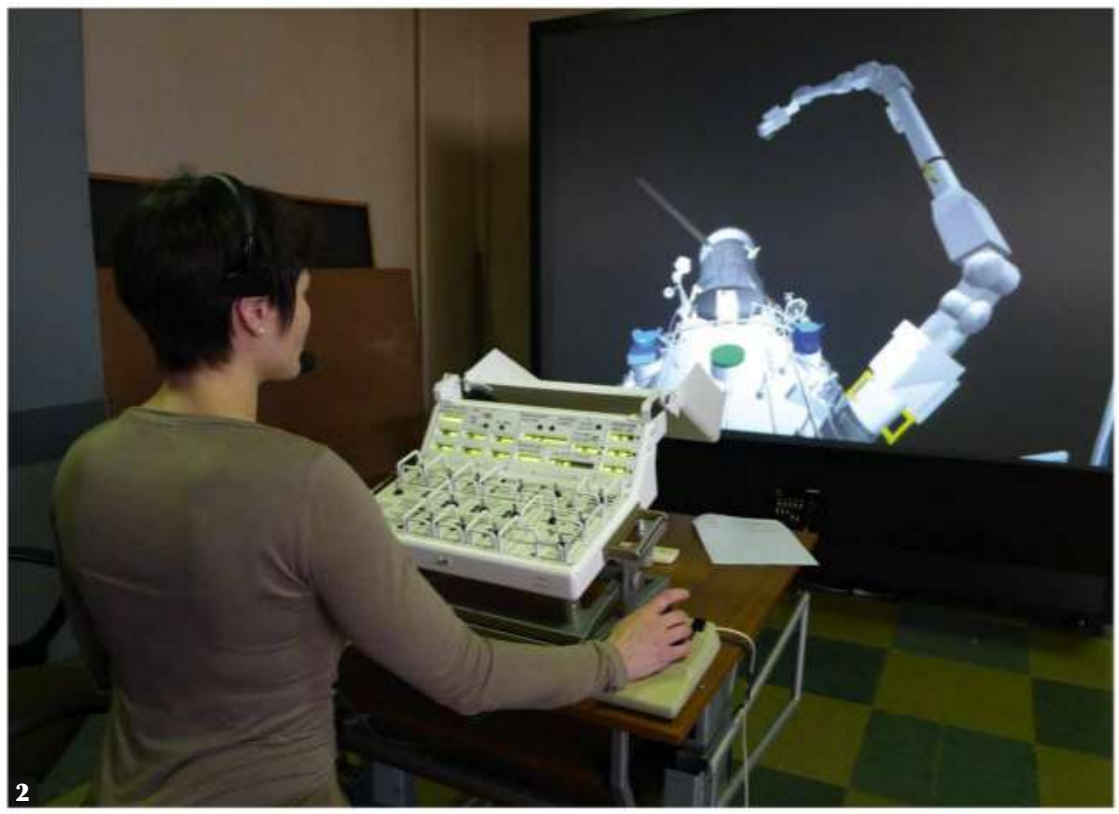

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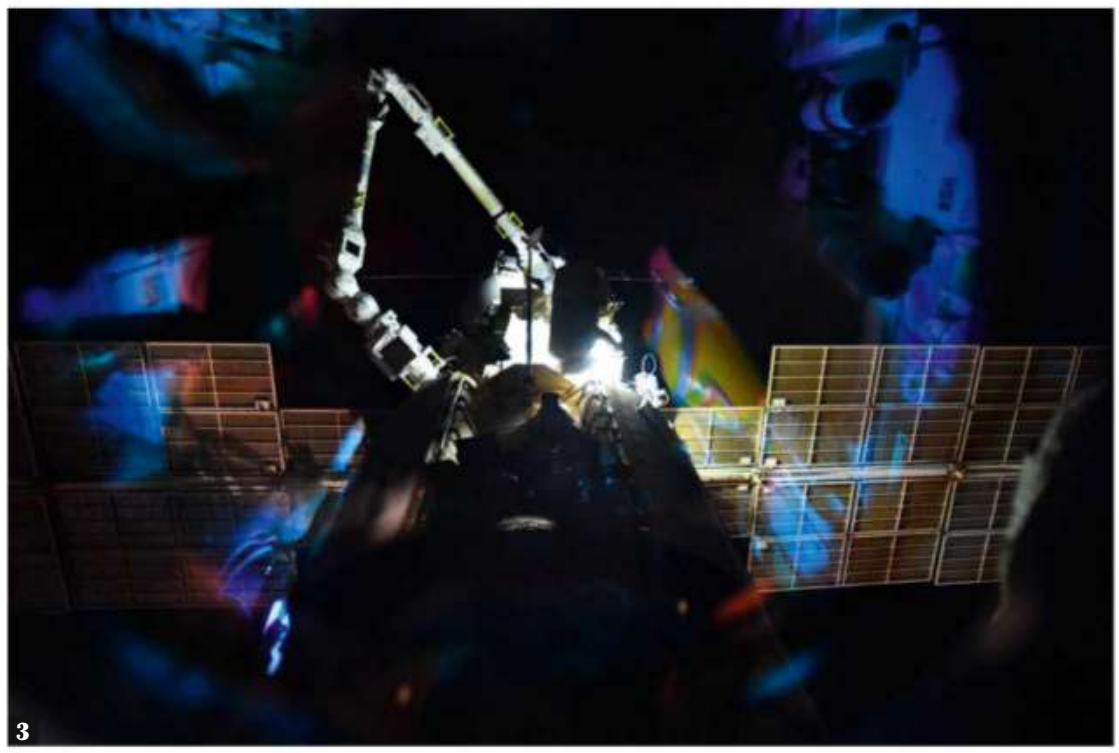

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ESA X3, NASA/JSC

4

HORIZONS

ENVIRONMENT

3D-PRINTED TERRACOTTA REEFS COULD SAVE THE WORLD'S CORALS FROM DEVASTATION

The artificial structures mimic the natural complexity of a reef and hope to attract marine organisms to support its regeneration

OFER BERMAN

WHY ARE CORALS SO IMPORTANT?

Coral reefs are often called the 'rainforests of the sea'. They're the habitat for a number of organisms, from the smallest invertebrates to enormous species that are fished commercially. All life – microbes, small animals, everything – depend on the coral reefs.

They're hugely important for coastal communities, for livelihoods, for the economy, for tourism. Corals also help to break waves so that they don't erode islands and coastal cities. Whether directly or indirectly, we're all in some way benefiting from corals.

WHAT DOES THE STRUCTURE OF A REEF LOOK LIKE?

If you strip away all of the living coral and the sponges and different things that make up the reef, you're left with something that's almost like a piece of rock. But as corals and other reef-building creatures settle and start to grow on this structure, they start to build and form the reef.

Existing artificial reefs have difficulty replicating the complexity of coral habitats and hosting reef species that mirror natural environments. What we're doing in our research is basically extracting the core characteristics of a reef by using 3D imaging and modelling. If you imagine throwing a blanket over the reef, you'd see the shape of the blanket. We're basically taking this shape and mimicking it.

HOW DO YOU SCAN THE REEFS?

Our partners from the University of Haifa, Israel, have taken thousands of underwater images that they have stitched together in imaging software. This generates a realistic model of the reef that's extremely accurate with lots of fine-scale details. You can move it around, you can zoom in on it, everything like that. And also you can tag and label different coral species.

We partnered with a 3D-printing and design team from the Technion-Israel Institute of Technology to translate information and put it into computer-aided design (CAD) software, which can then be read by the 3D printer. The printer will basically try to create the same complexity and detail as the design that we fed it.

HOW DOES THE PRINTING PROCESS WORK?

3D printing comes from an industry term called 'additive manufacturing'. It's as simple as it sounds. It's literally adding and building layers on top of each other. The printer will start layering the outline of the structure and will continue to build upon that. It layers it in hexagonal shapes. The printer knows how it should interpret the design and how it should add the layers of material.

We use terracotta clay that becomes ceramic when you fire it in the kiln. Once it's been fired it maintains its porosity, which is very important for an underwater structure. It also has similar properties to the actual coral skeleton.

WHAT SUCCESS HAVE YOU SEEN SO FAR?

We've deployed these reefs in the Gulf of Eilat in the Red Sea. At the moment, we're still in the phase of monitoring and collecting data. We've deployed 3D-printed ceramic tiles made from the same material, using the same process, just not such complex, massive structures.

We wanted to do a study to understand how the reef organisms would interact with the material. We wanted to find out how they'd settle on the structure, what kind of species

Layers of terracotta clay are printed on top of each other to form the artificial reef, based on computer models of real reefs

“The 3D CAD models can be uploaded to the internet. Anyone with the 3D-printing equipment required can take the CAD models and build a reef”

are able to settle on it, and whether it would be the same species that you’d get in a natural coral reef.

It’s been known for a while that terracotta is a great material for coral organisms and the way we’re using it has been working really well. We knew reef-building organisms would settle on a test reef if we added them, but on the reefs we deployed in the Gulf of Eilat, we’ve seen all the main reef-building organisms settle on them naturally.

We’ve been monitoring those structures with photography and soon we’ll begin monitoring them using environmental DNA. Hopefully we’ll see the same further enhancement [of the reef] and a bigger increase in biodiversity than you’d get if you just put a block of concrete or something in the water.

CAN THIS TECHNIQUE BE REPRODUCED IN OTHER PLACES?

That’s the idea. We wanted to implement an algorithm and a model that could be employed for any coral reef that needs support. So you could go and take 3D scans and build models of reefs in Colombia, Panama, Brazil... wherever it’s needed.

The 3D CAD models can be uploaded to the internet and then are available for anyone to download for free. Anyone with the 3D-printing equipment required can take the CAD models and build a reef. Researchers at other institutions around the world have already started doing this.

WHAT ARE THE NEXT STEPS FOR THE PROJECT?

Well, the dream is, if we can get some big funding, we would like to implement this project in several coral reefs all over the world.

Our philosophy is that we want to help all coral reefs that are degrading. The idea is to have a massive coral reef restoration project using our structures for wherever people need to add to reefs, to allow corals to settle and to grow. People anywhere in the world could use our technology. We’re really looking for people that are able to help us, to work with us, to help to contribute to the dream of protecting the reefs.

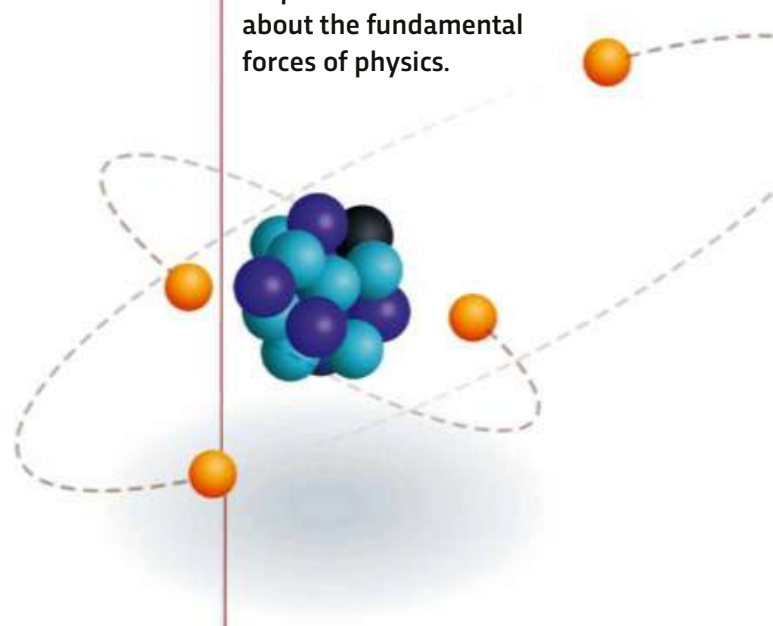
NATALIE LEVY
Natalie is a PhD candidate at the Mina and Everard Goodman Faculty of Life Sciences at Bar-Ilan University, Israel.

THE FUTURE'S BRIGHT...

As a remedy to all the bad news that dominates the airwaves, let us prescribe you a small dose of feel-good science. Each issue, we'll give you a rundown of the latest breakthroughs that hope to solve humanity's biggest threats. From algae-powered tech to drones that aid pollinators, here you'll find multiple reasons to feel hopeful for our future...

A miniaturised Deep Brain Stimulation system is showing promise in treating Parkinson's disease in trials at Southmead Hospital, Bristol. It delivers electrical impulses to targets deep within the brain, overriding abnormal brain cell firing patterns caused by the disease.

Scientists at the Facility for Rare Isotope Beams (FRIB) at Michigan State University are aiming to create variants of elements never before seen on Earth. These new isotopes could help us to learn more about the fundamental forces of physics.



YEARS TO GO

25

A eye taken from an organ donor has been brought back to life by a team at the University of Utah. The researchers were able to restore the function of photoreceptors that had been dead for five hours. The finding could help to establish the causes of macular degeneration.

20

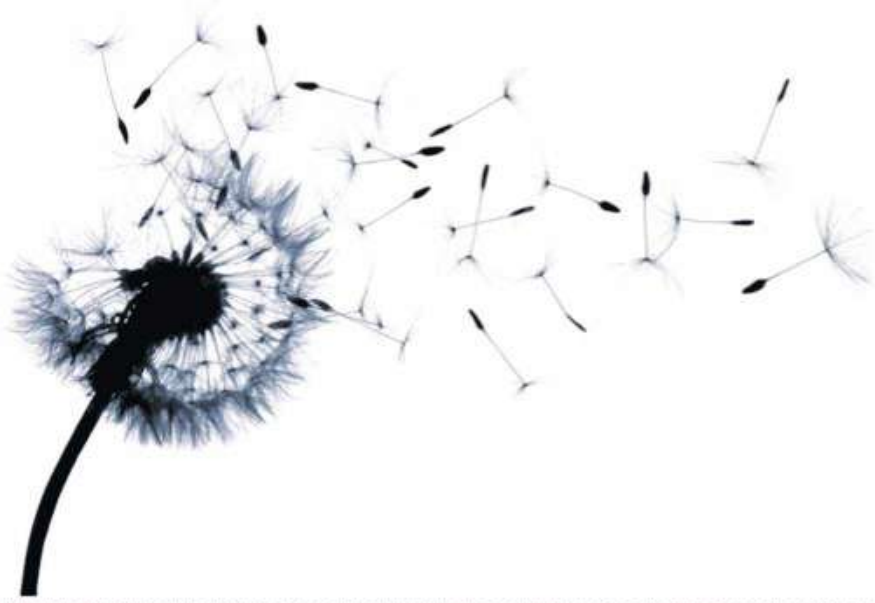
A growth factor found in the brain fluid of young mice can boost memory in older mice, a Stanford University study has shown. The researchers now plan to investigate the potential for using the same technique in humans.

15

Future generations of tech could be powered by algae. Researchers at Cambridge University have created a system the size of an AA battery that can power microprocessors using photosynthesis.

Patients undergoing robot-assisted surgery for bladder cancer removal and reconstruction spent 20 per cent less time in hospital and had 52 per cent less chance of readmission, a clinical trial led by scientists at UCL and the University of Sheffield has found.

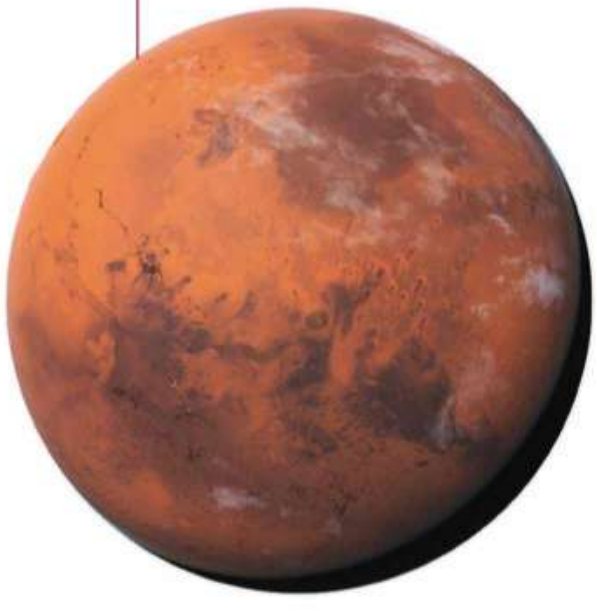
Satellites and drones could help to protect pollinators from extinction, according to a team at the University of Exeter. The images produced by the devices could help researchers to better identify habitats and behaviour to aid conservation efforts.



The cargo spacecraft Tianzhou-4 launched to deliver supplies, fuel and experiments to China's new Tiangong Space Station, which is still under construction. The Chinese Manned Space Agency hopes to finish the new station before the end of 2022.

10

SpaceX president Gwynne Shotwell said they will "put people on Mars within the next decade". The energy needed to launch a spacecraft to Mars depends on the positioning of it and Earth: the next lowest-energy launch period occurs in 2033.



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Non-invasive brain stimulation has been found to help smokers quit by reducing their cravings. Using the technique, patients were 139 per cent more likely to stay off cigarettes for three to six months after their last smoke.

0

The world's first flying taxi and delivery drone airport was opened in Coventry for summer 2022, and will later be redeployed in cities around the world. The port can run using on-site hydrogen fuel cells that generate zero carbon emissions.

ALAMY X2, GETTY IMAGES X5, NORTH BRISTOL NHS TRUST, PAOLO BOMBELLI/UNIVERSITY OF CAMBRIDGE, GODAI/WIKIPEDIA

COMMENT

TRAVELLING TO THE EDGE OF TIME

The James Webb Space Telescope won't just show us the furthest reaches of space, it'll take us back to the dawn of the Universe too...

From a tropical rainforest to the edge of time itself, James Webb begins a voyage back to the birth of the Universe" – so went the launch narration when astronomy's latest superpowered space explorer, the James Webb Space Telescope (JWST), lifted off from French Guiana on Christmas Day. Like most launch announcements, it employed a bit of poetic licence to add to the drama. But now that JWST is settled into its orbit and sending

back its first calibration images, we might well ask: what will this instrument tell us about the past, and how does that even work?

Characterising a telescope as a time machine is both overstating and understating its abilities. The telescope itself doesn't travel through time, but what it does is much more profound than just giving us clues about the past (as, for instance, an archaeological dig, or the discovery of an ancient relic would). Telescopes peering out to distant reaches of the Universe can see our cosmic history, directly. JWST can voyage back to 'the edge of time' not by actually going anywhere, but by sending us direct images of some of the earliest moments of the Universe – showing us what it would have looked like if we had actually been there, more than 13 billion years ago, watching the first galaxies form. It's able to do this partly because of the technology, which includes extraordinarily sensitive sensors and a 6.5-metre primary mirror, and partly because of this one weird trick enabled by Einstein's relativity.

One of the foundational principles of relativity is that everything you see is in the past. There's nothing special about telescopes in that regard. It is, in fact, impossible to see the present moment at all. Because light takes time to travel (about a second for every 300,000 kilometres), the image you see of a distant thing has already aged by the time it's reached you – you're seeing the thing as it was some time in the past. It's not noticeable in daily life because light speed is so fast that when you look at something on the other side of the room, it's only a handful of nanoseconds in the past, from your perspective. But a space telescope can see distant stars whose light has been travelling for hundreds or thousands of years, and galaxies so far away we're seeing them as they were billions of years ago.

With the Hubble Space Telescope, we've already been able to watch galaxies shine and stars explode within the first few billion years after the Big Bang itself. Hubble has even caught glimpses of especially bright galaxies in only the first few hundred million years – at a time when the cosmos was only just beginning to become awash with starlight. By studying those images, we're learning about the conditions of the Universe back then: how much hotter and more crowded it was, how much of the ambient gas was ionised by the light of the newborn stars, how matter was coming together to form the galaxies hosting those stars. And because our own cosmic neighbourhood doesn't appear to be unusual in the grand cosmic scheme of things, learning about the early development of some distant part of the cosmos is also telling us about our own past. And the more 'ordinary' that part of the cosmos is, the closer we are to observing the origins of everything around us now.

"We'll be able to see more than just the brightest and rarest representatives of the first generation of galaxies. With JWST, we'll be watching the very first collections of stars coming together all across the cosmos"

Prof Caitlin Casey, an astronomer at the University of Texas at Austin, who will be among the first to use JWST to study the distant cosmos, knows just how much JWST's giant mirror and high sensitivity matters.

"The main thing that's different is that JWST will go a factor of 100 times deeper than any existing images we have using ground-based telescopes or Hubble," she explains. "It's a HUGE gain in sensitivity, which allows us to increase the number of early Universe [first billion years] galaxies known by factors of 100."

Soon, we'll be able to see more than just the brightest and rarest representatives of the first generation of galaxies. With JWST, we'll be watching the very first collections of stars coming together all across the cosmos, lighting up their surroundings and setting the stage for the vast and varied Universe we see around us today. As astronomers, we hope that JWST will finally answer some of our most pressing questions about the origins of structure in the Universe. But even more than that, we hope that this new view of the deepest reaches of our cosmic history will present us with new questions we didn't even know enough to ask.

DR KATIE MACK
(@AstroKatie)
Katie is a theoretical astrophysicist. She currently holds the position of Hawking Chair in Cosmology and Science Communication at the Perimeter Institute for Theoretical Physics.

NERISSA ESCANLAR ILLUSTRATION: MYRIAM WARES

COMMENT

WHY DOES RESEARCHING BISEXUALITY MATTER?

It's Pride Month and the UK is aglitter with messages of love. But not all the letters of the rainbow alphabet have been able to shine...

DR JULIA SHAW
(@drjuliashaw)
Julia is a psychological scientist at University College London, the author of multiple best-selling books, and the co-host of the hit podcast Bad People *on BBC Sounds.*

The number of people who identify as queer in the UK Census has increased over the past few years. This trend is in particular driven by the rising number of LGBT+ identities among people aged 16 to 24 years. The most popular sexual identity within this emerging group is bisexual – the romantic and/or sexual attraction to more than one gender. Data from the Office for National Statistics (ONS) shows an increase from 0.7 per cent in 2015 to 1.1 per cent in 2019. Rather than a sudden new surge of bisexual desires, increased acceptance, legal protection and visibility are likely to be the cause of this increase.

But why should we count how many people are bi, or study what their experiences are? Research is young in this field, but we're already seeing that tossing all queer identities into one research bucket renders the unique struggles of being bisexual invisible. For a start, it's hard to even get an accurate sense of the exact number of British people who are bisexual. Many people who are attracted to people beyond one gender, shy away from the identity label 'bisexual'. When it comes to research, this reluctance has led scientists to come up with alternative ways to capture and categorise sexuality.

One of the most common tools used is The Kinsey Scale. First published in 1948 by biologist Dr Alfred Kinsey, it is used to place people on a spectrum of sexual attraction between entirely heterosexual and entirely homosexual, using a scale from 0 to 6. It also includes 'X' for those who are asexual. It was so successful that it is still the single most popular scale for classifying sexuality. It's often what people are indirectly referring to when they say, "Aren't we all a bit bi?"

When YouGov surveys conducted in 2019 used questions that mimicked The Kinsey Scale, researchers found at least a third of people aged 18 to 24 say that they are attracted to multiple genders. A startling figure compared to the 1 per cent reporting to the ONS. Only with research can we cut through the reluctance people have to say "I am bisexual", and find out whether those attracted to multiple genders need more support than those who aren't.

Since social scientists and other researchers have started to analyse the B, we have begun to

ILLUSTRATION: SCOTT BALMER

“Bisexual men are seen as lying, to themselves and others, because they are thought to be gay”

understand the struggles that uniquely endanger bi people. Research shows us that bi women are hypersexualised, and stereotypes that see bi women as promiscuous sexual playthings feed into people’s existing rape myths. Accordingly, studies have found that bisexual women are significantly more likely to be raped, repeatedly sexually assaulted, and to be the victims of intimate partner abuse than lesbian and heterosexual women. Had this research homogenised all women into one group, we might never have known that the stereotypes affecting bi women specifically place them at far greater risk of sexual victimisation.

A different cluster of toxic assumptions awaits bi men. Bisexual men are seen as lying, to themselves and others, because they are thought to be gay. And, particularly in the 1980s and 1990s, bi men were also seen as murderers in disguise, catching AIDS when having sex with men and giving it their female partners. This left many bisexual men isolated and alone, failed by educational campaigns that rarely moved beyond gay spaces. We need to acknowledge the unique needs of bi people, including a specific focus on bi men. If we don’t, we fail a huge amount of the population. Armed with bi-specific research, we stand a better chance of winning the fight back against the societal biases and misconceptions that hold bisexual people down.

As a young researcher, I didn’t know anyone else who was bisexual in my field, or, for that matter, in *any* field. It was rarely mentioned, not even in lectures specifically on sex and sexuality. When I graduated with my PhD in 2012, I had no idea how useful my background in criminal psychology would come to be when I turned my gaze to studying bisexuality. For my new book, *Bi: The Hidden Culture, History And Science Of Bisexuality*, I have found and spoken to researchers across the globe and in various disciplines who are all fighting for change

I want the world to be a safer place for people like me. The best way that we can achieve that is to visibly support bi people this Pride Month. Let’s not allow the ‘B’ to slip into the shadows of its colourful siblings.

BBC SOUNDS

Listen to Dr Julia Shaw on the *Bad People* podcast, available on BBC Sounds.

COMMENT

AI WILL NEVER THINK LIKE A HUMAN... AND THAT'S OKAY

There's no point getting frustrated with artificial intelligence when it doesn't do what we expect it to. Instead, we should focus on the ways it can help and support people

Since the start of the pandemic, AI developers have deployed hundreds of machine learning tools to help diagnose COVID-19. The promise: to find patterns in the medical data like an algorithmic version of the television character Dr House. Recently, researchers have discovered that these AI tools were overhyped. Instead of discovering relevant connections between cases, the algorithms were making a litany of false assumptions, including predicting COVID cases based on the text font that hospitals happened to use in their documents.

This does not mean that machine learning is useless. It means that we need to better understand the strengths and limitations of AI.

"Animals are a more useful comparison to AI, because they, too, perceive and engage with the world differently from humans"

DR KATE DARLING
(@grok_)
Kate is a researcher at MIT, where she investigates technology and society, and studies human-robot interaction.

To a human, it's obvious that a text font is not a good predictor for infectious diseases. But to a machine, that's not obvious at all. AI may be able to use informational input to make predictions, but it's not aware of what it's doing. It doesn't understand concepts or context, and is easily thrown off by biased or mislabelled data that wouldn't fool a four-year-old. As machine learning expert Janelle Shane explains in her AI weirdness book *You Look Like A Thing And I Love You*, the mistakes machines make feel absurd to us because they don't perceive the world like we do.

Unlike AI, human intelligence is extremely generalisable and adaptive. We're flexible thinkers, understand broad concepts, and we can contextualise unexpected results or situations. And yet, a Google image search for 'artificial intelligence' in 2022 returns mostly pictures of human brains. It's not just our stock photo images: we use our own intelligence as a model when talking about AI, whether in casual conversation, science fiction thrillers, or in our news headlines. In part, this is because the AI pioneers originally set out to understand and recreate human intelligence. So far, they haven't succeeded.

It's not that technology isn't smart or getting smarter. Given the right data, training and circumstances, machines are great at computation, predictions and recognising patterns. My phone can do calculus and parse voice commands (at least most of the time). Newer deep-learning methods can leave human ability in the dust. In 2016, when an AI system named AlphaGo beat the best Go player in the world, it made a move that astonished the experts: a move no human player would ever have thought to try. So rather than viewing AI as a less-developed version of ourselves, maybe it's time to embrace our differences.

Roboticist Rodney Brooks once wrote, "It is unfair to claim that an elephant has no intelligence worth studying just because it does not play chess." Animals are a more useful comparison to AI, because they, too, perceive and engage with the world differently from humans. They sense things we can't, and are totally oblivious to things that are obvious to us. That's why, throughout history, we've relied on animals to help us do things we couldn't do alone. We domesticated beasts of burden to help plough our fields. We've used canaries in coal mines, created pigeon postal services, and taught dolphins to recover lost underwater equipment.

You wouldn't trust a dog to give you a medical diagnosis or relationship advice, for example, but you might trust it to sniff out explosives, assist the blind, or provide therapeutic comfort. Similarly, AI may be lousy at appreciating your jokes or responding in an unexpected situation, but it can navigate traffic, detect safety hazards in nuclear plants, and collect data on Mars. Robots like the PARO, a snuggly medical device that looks and moves like a baby harp seal, are even surprisingly effective in therapy, when using real dogs isn't feasible. The point isn't that AI should replace dogs. The point is that the animal thought exercise lets us set aside the human comparison and imagine what AI can help us with that we can't do alone.

Understanding the strengths and limitations of AI is key to avoiding the types of harmful mistakes we're seeing today. The idea that we're dealing with a different kind of intelligence inspires us to leverage this technology to support people, rather than replacing them. It encourages us to invent new practices and find new solutions, rather than recreating what we already have. And it prompts us to think more creatively and inclusively about how to situate AI in our infrastructure, workplaces and personal lives. The best possible future isn't one in which our technology thinks or acts like a human. It's one in which we've envisioned a better world, and partnered with technology to create it.

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REALITY CHECK

SCIENCE BEHIND THE HEADLINES

Vampire electronics | Highly sensitive people | Girls and physics

ANALYSIS

VAMPIRE ELECTRONICS: HOW MUCH POWER DO THESE DEVICES REALLY DRAIN?

Can you save £££s by switching off appliances at the mains, as suggested by some headlines?

"The European Union has regulations on standby consumption of electronic devices in order to minimise the amount of electricity being used on standby"

BBC

Visit the BBC's Reality Check *website at* ***bit.ly/reality_check_*** *or follow them on Twitter* ***@BBCRealityCheck***

In April, British Gas published a report claiming households could save an average £147 per year on their energy bills by switching off devices that drain power when left on standby.

The finding sparked the latest conversation about so-called 'vampire electronics' – devices that consume electricity when they're on standby mode or at other times you may not think they are – such as phone chargers plugged in at the wall but not connected to a phone, which will add a few pence to your bill.

So how much power are these devices draining, and can we do anything about it to lower our bills?

In its report, British Gas named set-top boxes, satellites, internet routers and TVs as the top three worst offenders when it comes to wasting money by being unnecessarily left on standby. Microwaves, games consoles and computers also drain a lot of energy on standby, it said.

It used a survey carried out by YouGov to understand appliance use in UK households in April 2022, and combined that with their latest energy prices to understand the potential cost of vampire gadgets, a spokesperson for British Gas said.

"This is a 'could' scenario and 'up to' this amount – this is based on what people are telling us, so it's not an exact science but our aim is to start the conversation to highlight the tips around turning things off when not in use," the spokesperson said.

"A good top tip is to replace things with more energy-efficient models when you can and we especially see big savings from items like washing machines and dishwashers amongst our customers."

Craig Melson, associate director for climate, environment and sustainability for trade body techUK, says it's hard to calculate a figure for the average percentage of bills which come from vampire devices as there are too many variables.

"We all have different tariffs, and some people use flexible energy services and smart meters to lower bills and have differing devices," he says.

Others have also attempted to name a figure, however. Energy Saving Trust advises that households can save around £55 a year just by turning appliances off standby mode.

"Most electrical appliances can be turned off at the plug without impacting their programming," a spokesperson said.

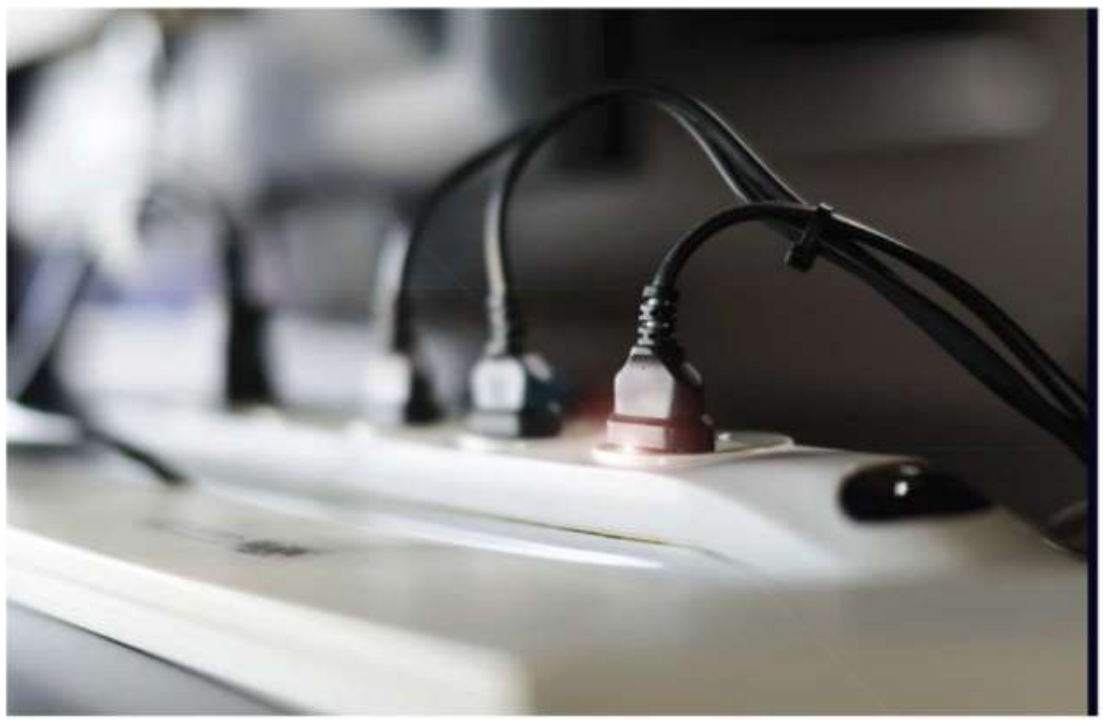
An earlier 2012 study highlighted home entertainment systems, VCRs and printers as high users of energy on standby mode. And another 2017 study cited Energy Saving Trust findings in 2014, which stated that standby demand can range from 9 to 16 per cent of a household's total electricity consumption.

But the problem with using older studies as a basis for understanding how much money we are currently wasting due to vampire devices is that standby modes have become far more energy efficient in recent years.

"Since the mid-2010s, the European Union has had regulations on standby consumption of electronic devices in order to minimise the amount of electricity being used on standby," says Sara Walker, professor of energy at Newcastle University.

This has led most new devices to use far less energy than older ones. Meanwhile, Walker notes, the number of devices that we own, and the number that are internet-enabled, has increased.

"Although one device might use less, overall, we're still using about the same amount of electricity for our appliances, because we're using them



We've all got more appliances in our homes now, so it makes sense to switch them off when not in use

GETTY IMAGES X2

more, and we own more of them," she says. "When you've got 10 or 15 of those in the house, as opposed to two or three, it can still add up over a full year."

Turning off these devices at the plug when not in use is a fairly easy win on energy bills, says Walker.

"Obviously, this is a no-cost measure, which has its advantages for people who are really struggling with their bills," she says.

However, manufacturers should also make sure they make this easy for us, she adds. For example, by making sure you don't need to reset a clock to make a device work when you turn it back on.

Melson says the rollout of smart meters in the UK is also helping by informing people how much they are spending on electricity. Meanwhile, investing in low-cost smart plugs and smart home tech – which can cost under £20 – allows you to power devices down using your phone.

However, Walker explains that for most people, gas consumption is a larger part of overall energy consumption than electricity.

Small measures can help here too, such as using the shower instead of the bath to cut down on hot water demand, draught-proofing by closing the curtains and using draught excluders on doors, and wearing warm clothing. And for those who can afford it, insulation – starting with the loft – is a great way to reduce the heat loss, she adds.

Walker notes that our electricity consumption today is connected to social networks and the way that we like to use our free time. Much of our energy use comes from surfing the internet, streaming or watching television, or cooking.

"Some of that is a personal choice, but even so the price that we pay for the energy in order to do those things is outside of our control, it's market forces," she says. "And there's a limit to our individual power to reduce that."

by **JOCELYN TIMPERLEY**
(@jloistf)
Jocelyn is a freelance climate journalist.

REVIEW

HIGHLY SENSITIVE: IS IT THE SAME AS BEING SHY OR INTROVERTED?

Recently, several celebrities have announced that they are 'highly sensitive people'. What does this term mean, and how can you spot the signs?

Last year the singer Lorde became the latest celebrity to identify as a "highly sensitive person", telling *Vogue* that her personality profile means that she just "isn't built for pop star life" and that she needs long stretches of time to be by herself to recover from the demands of her work.

Lorde joins other superstars, such as Kanye West and Nicole Kidman, who have also labelled

themselves in this way, apparently finding that it helps them make sense of their own experiences.

ABOVE Kanye West has claimed that he is a highly sensitive person

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WHEN DID THE TERM 'HIGHLY SENSITIVE PERSON' ARISE?

These celebs did not invent the term 'highly sensitive person'. It originated in an obscure 1996 counselling paper by the US psychologist Elaine Aron and then gained traction in a much-cited 1997 research paper that she co-authored with her husband Arthur Aron, in which the pair claimed the highly sensitive personality profile was related to, but different from, being shy or introverted. Moreover, a key feature of being a highly sensitive person, they observed, is having "sensory processing sensitivity".

WHAT IS SENSORY PROCESSING SENSITIVITY?

Based on interviews that the two Arons conducted with dozens of sensitive students, they concluded that having sensory processing sensitivity manifests in various ways, including being more sensitive than usual to "subtleties, the arts, caffeine, hunger, pain, change, overstimulation, strong sensory input, others' moods, violence in the media, and being observed".

"Studies have identified brain differences in highly sensitive people compared with controls"

Overall, highly sensitive people – which the Arons estimated accounts for between 15 to 20 per cent of us – are more affected by the external world than average, they reflect on and process things more deeply, and they are more empathic.

It's worth noting there's a related concept in the psychological literature, but one that's focused more on kids. It states that a minority of children are like 'orchids', in being highly sensitive to the environment of their upbringing – wilting when it's challenging and thriving when it's supportive. This is in contrast to the 'dandelion' majority, who outside of neglect, mostly do just okay, regardless of their positive or negative circumstances.

HOW CAN I DETERMINE IF I'M HIGHLY SENSITIVE?

As part of their investigations, the Arons created a new personality test, aptly named the Highly Sensitive Person Scale. To find out if you're a highly sensitive person, see if you agree with some of these example items from the scale: Are you easily overwhelmed by strong sensory input? Do other people's moods affect you? Are you particularly sensitive to the effect of caffeine? Do you find it unpleasant to have a lot going on at once? Do you startle easily? Are you bothered by intense stimuli, like loud noises or chaotic scenes? You probably get the picture. There are 27 items like these in the formal scale – and the more you agree with, the more likely that you are a highly sensitive person (if you want to delve deeper, Aron also has a free test on her website, **hsperson.com**).

WHY ARE SOME PEOPLE HIGHLY SENSITIVE?

The Arons and their research colleagues believe that being a highly sensitive person runs in families and that it has a biological basis, including a greater than usual sensitivity to stress. At a neural level, several brain-imaging studies have identified differences in highly sensitive people compared with controls, such as increased activity in higher-order visual processing regions during visual tasks, and greater activity in empathy-related neural regions when looking at images of a partner's face.

In a review they published in 2019, Aron and her colleagues stated that "high sensory processing sensitivity individuals may readily intuit, 'feel' ➤

In interviews, Nicole Kidman has said that most actors are highly sensitive people

and integrate information, and respond to others' affective states...", although they also acknowledged that research into the biological basis and causes of being a highly sensitive person is "still in its infancy".

Perhaps unsurprisingly, another line of research has documented that highly sensitive people are at increased risk of psychological and emotional difficulties; there are also still-to-be-worked-out links between the sensitive personality profile and conditions such as autism, which also frequently involves heightened sensory sensitivity.

HOW CAN HIGHLY SENSITIVE PEOPLE COPE WITH STRESS OR FEELINGS OF BEING OVERWHELMED?

If you think you might be a highly sensitive person, Aron and her colleagues have stated that you might be especially likely to benefit from mindfulness-based interventions to help you cope with feelings of stress or being overwhelmed, or indeed any kind of intervention that gives you tools for managing your emotions and emotional reactivity (you could consider cognitive behavioural therapy, for instance, or mindfulness-based cognitive therapy or acceptance and commitment therapy). According to Aron and her collaborators, recognising that you are a highly sensitive person could be an important first step.

If the concept of a highly sensitive person resonates with you and helps you manage your own mental health, that's surely a good thing. But it's worth also noting that from a scientific perspective, the concept is not without its critics. Many personality researchers believe the highly sensitive person concept is really not so different from being a strong introvert, highly emotionally reactive (i.e. highly neurotic) and open to experiences – all aspects of personality that are already captured by the popular and well-established Big Five model of personality. For instance, in a detailed statistical critique published last year, a pair of German psychologists concluded that while that the Arons' influential paper from 1997 "provided some interesting ideas" it's also the case that "the empirical basis for sensory processing sensitivity is currently weak".

by **DR CHRISTIAN JARRETT**

Christian is a cognitive neuroscientist, science writer and author.

COMMENT

PHYSICS: DO GIRLS AVOID IT BECAUSE IT'S TOO HARD?

In late April, head teacher Katharine Birbalsingh commented that girls didn't like physics and are put off it because of the hard maths

In 2021, 23 per cent of students taking physics A-Level in England were female. Five years ago it was 21 per cent, so any progress is glacial. In April, while giving evidence to the parliamentary Science and Technology Committee, Katharine Birbalsingh, a head teacher and chair of the government's Social Mobility Commission, was asked why this was, particularly in reference to her own school where only 14 per cent of physics A-Level students were female. She replied that they just didn't like it and were put off by the hard maths. The evidence suggests otherwise.

Firstly, in 2021 girls did (a bit) better than boys in both GCSE and A-Level maths. Secondly, the maths in physics A-Level cannot be harder than the maths in maths A-Level – and 39 per cent of maths A-Level students nationally are girls (and 59 per cent in Birbalsingh's school). So given girls do well at maths when they take it and are more likely to study maths at A-Level than they are physics, it doesn't follow that it's the maths that is putting them off. So what is behind the gap?

Let's start with A-Level choices. When students choose their subjects, they are influenced by three main considerations: what they want to do as a career (including university requirements, if relevant), how much they like each subject at GCSE, and what their friends are doing. An Institute of Fiscal Studies report found that while girls see science and technology careers as well-paid and secure, they are put off by their perception of them being male-dominated, particularly in the physical sciences, engineering and computer science. In those sciences where women are at least equal in career representation, such as medicine, veterinary sciences and biology, there is a high female representation at university. All these subjects place a greater emphasis on biology and chemistry than physics. This results in a negative feedback loop where girls are drawn towards fields with more women and pushed away from fields with fewer women.

The Institute of Physics and the Institute of Fiscal Studies both highlight that girls are less satisfied with physics teaching at school than the other sciences. Compounding this issue is that girls are less likely to see themselves as physicists ('self-concept') and are also less confident in their ability, despite performing

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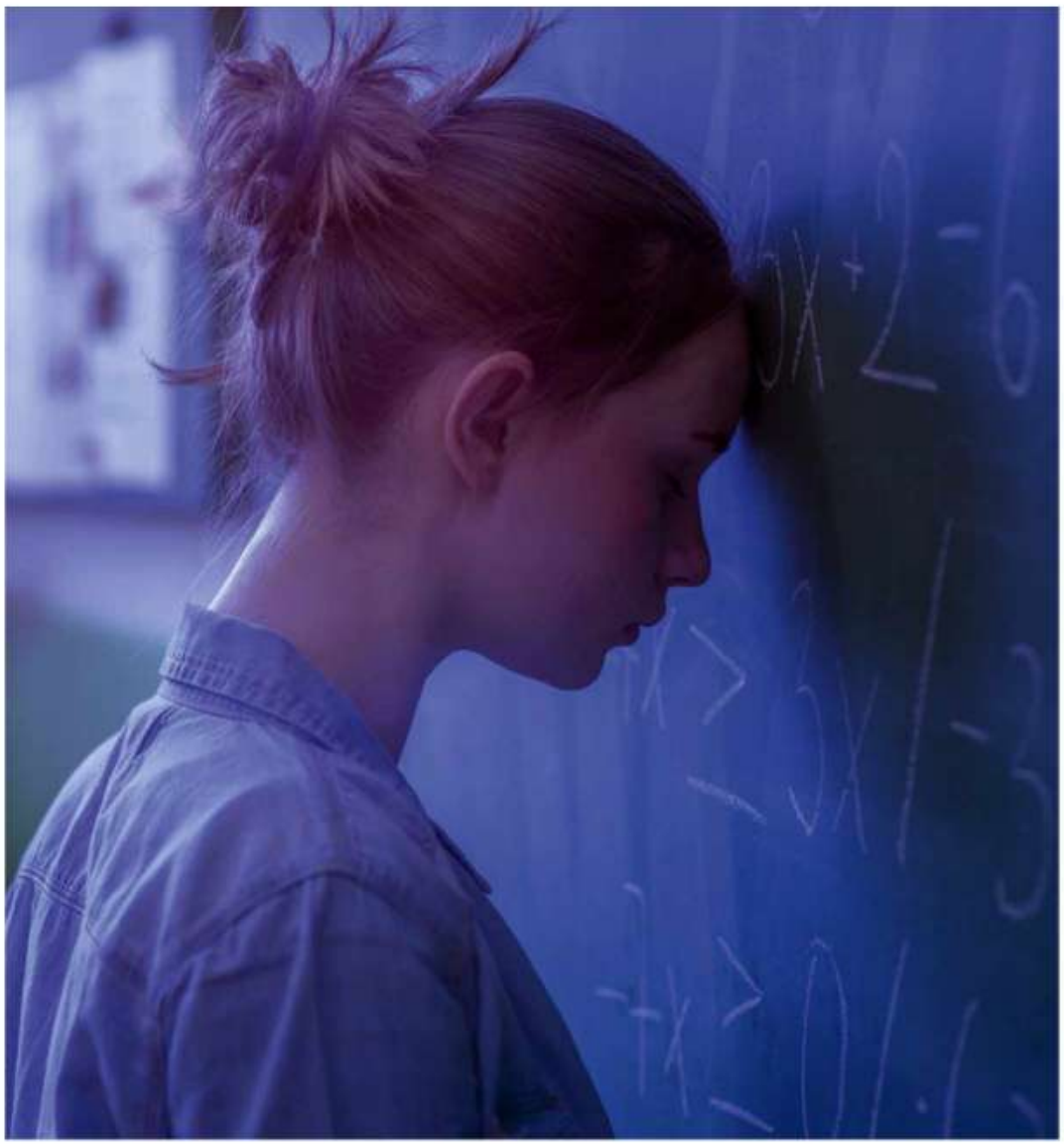
"While girls see science and technology careers as well-paid and secure, they are put off by their perception of them being male-dominated, particularly the physical sciences"



just as well as boys. The reasons for this are many – and go all the way back into infancy. Parents differ in how they judge the ability of sons and daughters in toddlerhood and in how they praise their children. This carries over into school, with teachers tending to overestimate boys' ability and underestimate girls' ability in maths.

The Institute of Physics has warned explicitly about the need for a whole-school approach to avoid lazy stereotypes around girls and physics, as even throwaway comments can have a great cumulative impact on girls as they contemplate their futures. As an interesting aside, the proportion of female computer science graduates in the US dropped from 33 per cent in the early 1980s to under 20 per cent now – a decline precipitated by the introduction of the personal computer, and marketing campaigns aimed almost exclusively at boys.

ABOVE Lazy stereotypes and throwaway comments about girls and physics can have huge impact

It is natural that students will be influenced by which subjects their friends are picking. A study from Switzerland showed that even when girls and boys start the school year with similar levels of interest in science, this changes under the influence of their peer group, with girls starting to prefer science less. In single-sex schools, both boys and girls are more likely to choose A-Level physics, but the effect is more pronounced for girls. The mirror problem exists for boys and subjects like English, languages and psychology, which can be seen as 'girl subjects'.

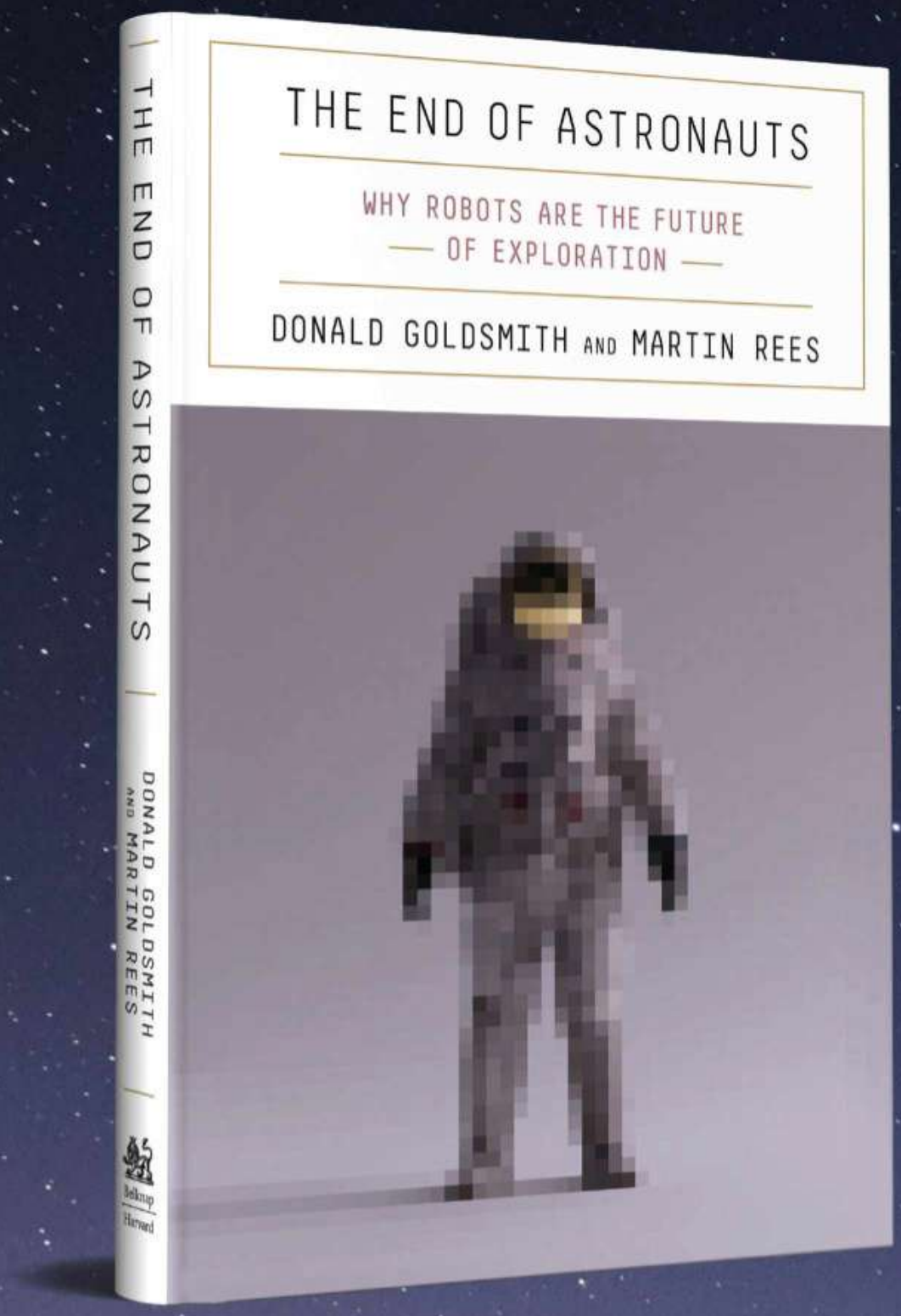
The above issues are interconnected, but I believe they are made worse by our curriculum. We are unusual in high-income countries by asking 16-year-olds to specialise in three subjects – in most countries, students take at least five and often more until they leave school. One impact of three subjects at A-Level is that anyone considering science as a career is forced to choose two out of three from chemistry, biology and physics, since maths A-Level is important across the sciences. A second impact is that as girls perform better across the board at GCSE, they have more options at A-Level.

Physics, maths, engineering and computer science deal with topics from the very nature of existence to inventing new technology that can transform our lives and address society's biggest problems. They offer entry into well-paid, interesting and diverse careers.

There are solutions (and participation of women in physics degrees is much higher in some other countries), but they involve both addressing differences in how we treat boys and girls from the moment they're born and thinking again about how early we are asking our young people to specialise in their education. **SF**

by **PROF CHRISTINA PAGEL**
Christina is a mathematician and professor of operational research at University College London.

A world-renowned astronomer and an esteemed science writer make the provocative argument for space exploration without astronauts.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INNOVATIONS

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GO WITH THE FLOW

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FIVE OF THE BEST

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Chuck these in your bag for a safer, better experience p48

NEW TECH

IDEAS WE LIKE

The gadgets we're lusting after this month p50

↑ The RA180 amplifier (see p51) blends old-school style with modern audio technology

META QUEST 2

The popular Meta Quest 2 made up 78 per cent of VR headsets sold last year

11.2 million

The number of VR headsets sold internationally in 2021, according to the International Data Corporation

REVIEW

Can a VR headset provide peace and tranquillity?

Alex Hughes tries to relax with a screen inches from his face...

The headset is less hefty than others, to boost the Zen-like experience

Mindfulness is big business these days, particularly when it comes to the world of tech. The Calm app exceeded a $1bn valuation in the middle of the pandemic, and its mortal enemy, Headspace, boasts over 30 million users across 190 countries.

While meditation apps are popular, they aren't the only form of tech working their way into your mindfulness routine. HTC is looking to inject new life into virtual reality headsets by reframing its £499 VIVE Flow device as an on-the-go 'wellness' system. So, can a VR headset take me to an oasis of tranquillity?

THE PRACTICAL STUFF

Setting up the device is simple. All that's needed to get started is a smartphone that's compatible with HTC's headset, a power source and a USB-C. There's an app to download that connects your phone to the headset via Bluetooth. This turns your device into a remote control, with different parts of the phone's display acting as input buttons. Once set up, I put on the headset and used my new controller to peruse the VIVE Flow marketplace. This wasn't the most intuitive experience, requiring you to remember very precise points on your phone that you can't see. Many of the experiences the headset offers come at a cost, ranging from 50p to £20 or more. There are a few free experiences available in there, especially for those looking to find their inner Zen with a few short meditation exercises. For games or immersive experiences, prepare to hand over some cash.

TRANSCENDING TO ANOTHER WORLD

My first stop on the journey to tranquillity was BBC's *The Turning Forest*. In this experience, you're dropped into a vibrant cartoon-like jungle, with a narrated story. The lightness of the headset meant I could walk around enjoying it without constantly thinking about the hefty weight on my face. I crossed the sea on the back of a large creature, explored frozen lands and flew through the sky – a normal day in VR.

Spurred on by how much I enjoyed *The Turning Forest*, I looked for more experiential VR apps. I swam (or awkwardly walked around my living room) among corals and small fish, and strolled up a mountain while being told about its history.

While these experiences were easily my favourite part of the HTC VIVE Flow, I found the graphics were sometimes a letdown, with my surroundings being low resolution and somewhat grainy, especially when trying to replicate real-life situations.

Objects were often blurry, even when I adjusted the goggles to fit my eyesight. This comes down to a mix of low-resolution visuals, and movements that felt laggy. This is a feature that has caused motion sickness for people with VR in the past.

MEDITATING WITH VR

Strapping a 189g pair of goggles to your face, blinding you to your surroundings, doesn't sound that relaxing. But HTC has made the headset as light as possible, meaning after a while you can forget it's there.

The VIVE Flow headset connects to your smartphone via Bluetooth

In fact, this is one of the lightest VR headsets you can buy (the relatively light Meta Quest 2 weighs 500g, for comparison). This meant I was able to immerse myself for long periods of time – perfect for meditation.

My first VR meditation outing was called *Cosmic Flow,* where spirals and shapes fly past to the sound of windchimes and the odd gong. This was not for me. Feeling slightly overwhelmed and dizzy, I went back to the VR store and tried again.

I downloaded two apps that offered 'meditation experiences'. The first dropped me onto a beach during a sunset, with a voice talking me through a meditation session with wave noises in the background.

This was pretty Zen. Sure, I'd rather be on a real beach, but at 8pm on a Thursday this virtual one will do. Other meditation apps followed a similar format – placing me in some relaxing scenery and guiding me through a calming experience. Some were better than others, but overall, none of it felt like I was transcending to another cosmic plane. Sitting on a blurry virtual beach with gongs playing around you is hardly the nirvana that monks aspire to.

In comparison with other VR headsets, the HTC VIVE Flow is a lower resolution experience. This a sacrifice you make for the device's portability, but it does mean that the calming place you find yourself in is slightly blurry or, worse still, glitchy.

RATING: ★★★★★

PROS:

- Light and portable
- Only requires a smartphone and USB-C cable
- Varied apps for health, meditation, learning and gaming
- Easy to set up

CONS:

- Expensive
- Low visual quality
- Audio could be better
- Limited controls through smartphone

VERDICT

Did I experience peace and relaxation through virtual reality? No. However, I think some people could become used to the whole experience and start to find some tranquillity.

When the headset keeps you distracted with a detailed yet calming experience, that's when it worked best. But really, when there's £499 on the line, I think I would just prefer a good walk to clear my head. For overall value for money, this headset falls short of what I would expect, especially with cheaper, better quality VR headsets out there right now. As a wellness device, I'm not convinced the HTC VIVE Flow can fill that gap in the market. As a portable games console, a way to explore made-up lands, and learn about the world, I can see where the VIVE Flow could have potential.

3 CHEAPER WAYS TO ACHIEVE MINDFULNESS

GO FOR A WALK

It's a cliché, but a good walk is scientifically proven to improve your mental state. Go for a stroll in the morning and you can improve your sleep, speed up your metabolism and even boost your cognitive function. Studies show that the results can be even better when this walk is done at a brisk pace. Plan your walk in a green space and the nature around you will be a further benefit to your wellbeing. In a 2020 study, time spent in nature reduced anxiety in 29 per cent of participants.

MEDITATION APPS

If you like the idea of using technology in a mindfulness routine, there are lots of meditation apps out there. Two popular ones are Headspace and Mind. Both of these apps include guided meditation sessions, music, calming sounds, affirmations and other features to keep you calm, or help you work through stress. While you do have to pay for most of these apps, they are much cheaper than forking out hundreds of pounds on a VR headset.

BREATHING

You breathe all day, but if you take the time to slow it down and focus on that breathing, it is an easy and effective way to find calmness in your day.

A number of studies have shown that slow, deep breathing techniques are effective against anxiety, stress and insomnia.

The essentials... festival tech

After a two-year break, festivals are back. Don't set off for a weekend of music, food and mud without these

Nokia 6310 4G

£49.99, nokia.com

Replacing your £1,000+ smartphone for a £50 dumbphone for the weekend may not be a bad idea, especially if you're worried about pickpockets or have concerns about your own festival escapades.

The Nokia 6310 4G takes us way back with its classic design, complete with a physical keypad and 2.8-inch display (no touchscreens here). Although it's made almost entirely from plastic, it feels like it'd withstand your standard festival knocks and drops without issue – just be sure to keep it away from water, as there's no IP rating. You'll also want to take a better camera with you, as the 0.3MP snapper isn't up to much. But it's the outstanding battery life that makes the phone a festival must-have. With almost 20 hours of talk time and over 20 days on standby, it'll keep you in contact with friends and family for the whole weekend, and probably without needing a charger.

Loop earplugs

From £12.95, loopearplugs.com

No festival is worth risking your hearing for, and Loop's earplugs have to be some of the prettiest we've ever seen – and the cleverest. We tried out the Experience plugs, which reduce noise by 18-20 decibels while keeping sounds and voices clear. They do this by mimicking how your ears function, in order to deliver a natural sound at a reduced volume while avoiding the muffled noise you can often get with earplugs.

In use, the earbud sits snugly in the ear canal, with the loop part (available in silver, gold, black or rose gold) resting gently in the outer ear. They're lightweight and comfortable enough that you can easily forget you're wearing them, and they come with a pocket-friendly carry case to keep them safe when you're not.

APP: WHAT3WORDS

Never get lost again

Finding your friends is one of the great challenges of a festival, but the free app what3words solves this problem. It splits the world into three-metre squares, assigning each one a combination of three random words. These codes can be given to your friends so they can find the exact spot you've sent them, right down to a three-metre area. This is perfect for tracking your mates down in a small area packed with thousands of people. You can even save locations so you can get back to your tent with ease.

what3words.com

Available on iOS and Android

GoTenna Mesh

£166, gotennamesh.com

So you've got your phone, and a powerbank to keep it charged, but the problem is trying to get the signal to stay in touch with your friends. At a festival, the huge amount of people in one area can mean networks get congested and your texts take longer to send… or don't send at all.

There are a few ways to get around this, but our preferred option is the GoTenna Mesh. It consists of a pair of light signal devices that look a lot like USB sticks. When you connect your phone to them, you are able to send texts and GPS locations without needing any internet or signal.

They are small enough to fit in your pocket and have enough battery life to keep you going for the whole weekend. The range is quite limited, so if you and your friends are partying at opposite ends of a big festival, then you may struggle to reach each other.

Anker 313 Powerbank

£22.99, uk.anker.com

If you can't bear to be parted from your smartphone over a weekend, you are going to need a portable battery to keep your devices charged. The Anker 313 Powerbank is a great option. It's one of the slimmest 10,000mAh batteries you can buy, so it's easy to slip into your pocket or bumbag. It promises more than two full charges of an iPhone 12 and just over 1.5 charges of a Galaxy S20. You can charge anything from it, of course, just add a USB-A or USB-C compatible cable of your choice (you only get a micro-USB in the box).

Featuring Anker's PowerIQ and VoltageBoost technology, the 313 promises faster charging of power-hungry devices, but we liked having the option for trickle charging, which provides safe, optimised charging for low-powered devices, like wireless headphones and Bluetooth speakers.

Soundcore Motion Boom

£94.99, uk.soundcore.com

When the music on stage has stopped and you want to be able to carry on the party back at your tent, you need a portable speaker that's up to the job. Enter the Motion Boom, a powerful, waterproof speaker. On face value, we love its retro 'boombox' styling, complete with handy carry handle. But the real beauty is the performance of which this relatively compact speaker is capable. Vocals are crisp and clear; even with the bass boost on, the sound is confident and authoritative. With a 24-hour battery life, this should easily give you a weekend's worth of tent parties, plus it doubles up as a charging point if your powerbank is out of juice.

Ideas we like...

Our pick of the month's smartest tech

...a powerbank capable of 97 phone charges

Anker's latest powerbank can be described in one word: overkill. The PowerHouse looks like it could… well, power a house. Anker claims this device can charge your phone 97 times, a laptop 16 times or keep a light running for 82 hours. In other words, this is more what you use in a power cut, a long camping trip or a post-apocalyptic zombie world, rather than for quickly adding 10 per cent more battery to your phone. It has a plug, USB and car sockets, a digital display, LED light and a massive price tag to match its beefy size.

Anker 757 PowerHouse
$1,399 (£TBC), anker.com

↑ ...a good-looking amplifier

Looking at the Hi-Fi Rose RA180, we can't help but feel like the brand took inspiration from a toaster, throwing in a few cogs, switches and dials for a stylish steampunk take on the kitchen appliance. But these dials and switches aren't just for show. Hi-Fi Rose is going old school, allowing customisation across a range of audio settings. The RA180 uses Class AD amplification which results in a high-speed, accurate amplification stage, offering a more natural sound. Is it affordable? Absolutely not!

Hi-Fi Rose RA180
£5,499, eng.hifirose.com

↓ ...a worthy rival to the MacBook Pro

The Dell XPS 13 Plus could well be the new go-to laptop for Windows users, offering a stylish and powerful experience… albeit at a somewhat hefty price. The 13-inch laptop offers a clean layout which, we'll be honest, looks suspiciously like Apple's latest MacBook Pro model. With the XPS, you get a light-up touchbar for volume, brightness and other key controls, a Full HD+ display, a powerful Intel Core processor and a hidden trackpad.

Dell XPS 13 Plus
£1,298, dell.com

↓ ...intelligent wearable tech for the blind

There are plenty of smart glasses out there. Ray-Ban, Snapchat, and even the gaming company Razer have all made a pair! But in this crowded market, Envision's smart glasses easily stand out. That's because they have been designed for blind people. The glasses can scan the environment, reading signs, texts, recipes and other visual stimuli, before speaking them out loud. The glasses can also warn the individual of obstacles, and call friends and family for a video chat.

Envision Glasses
€3,268 (£2,760 approx), letsenvision.com

IDEAS WE DON'T LIKE...

...BUYING LAND THAT DOESN'T EXIST

Feeling crushed by the price of housing these days? Well don't worry, you can still be a homeowner... just not in the physical world. No, we're not talking about buying up property in *Sim City*, we're thinking about the desperate lunge for land currently underway in the metaverse. These digital worlds experienced through VR could soon be our future, and early fans are already making their purchases, spending millions on digital property, land and virtual consumer goods. Just like NFTs and cryptocurrencies, you likely won't hear the end of this 'innovation' for a while.

metaverse.properties

...A DRONE FOR THE SELFIE OBSESSED

There was a time in the very recent past when we, as a society, came together to mock selfie sticks. Well, now things seem to be stepping up a level with the selfie stick's tech-heavy brother – a selfie drone. Snapchat's latest device is a $250 drone that's dedicated to the world of social media, helping you capture short videos and photos. The drone has some genuinely impressive flight navigation and features, tracking and following the subject, which makes its role as a flying selfie camera feel like wasted potential.

Pixy
$249.99 (£TBC), pixy.com

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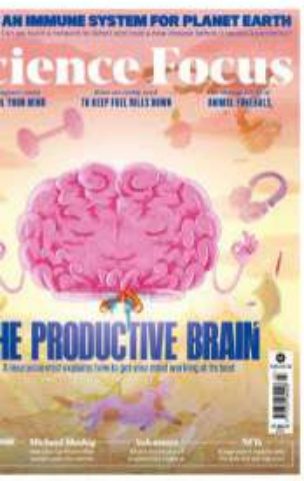

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PUSH IT TO THE LIMIT

SCIENTISTS GO TO EXTRAORDINARY LENGTHS TO EXPAND OUR UNDERSTANDING OF RADICAL PHENOMENA IN THE MOST EXTREME LABS ON EARTH

WORDS: KATHERINE NIGHTINGALE

THE DEEPEST (AND CLEANEST)

SNOLAB, ONTARIO, CANADA

Even a Bond villain might consider SNOLAB too remote for an underground lair. Earth's deepest and cleanest lab is two kilometres underground, part of a nickel and copper mine in Ontario, Canada.

The deep layer of rock between the 5,000m² lab and the Earth's surface shields it from the cosmic radiation that would otherwise interfere with its sensitive experiments. The lab searches for solar neutrinos (extremely small subatomic particles produced by the Sun) and dark matter, the estimated 27 per cent of matter in the Universe which remains a mystery to us. But situating a sparkling clean lab in a mine comes with its downsides. As well as a 1.5km walk from the lift to the lab, researchers and support staff must undergo a lengthy cleaning process involving showers, hosed-down boots and lab-laundered clothes to make sure that no mine dirt or particles make it into the facility.

The lab also contains the world's deepest underground flushing toilet.

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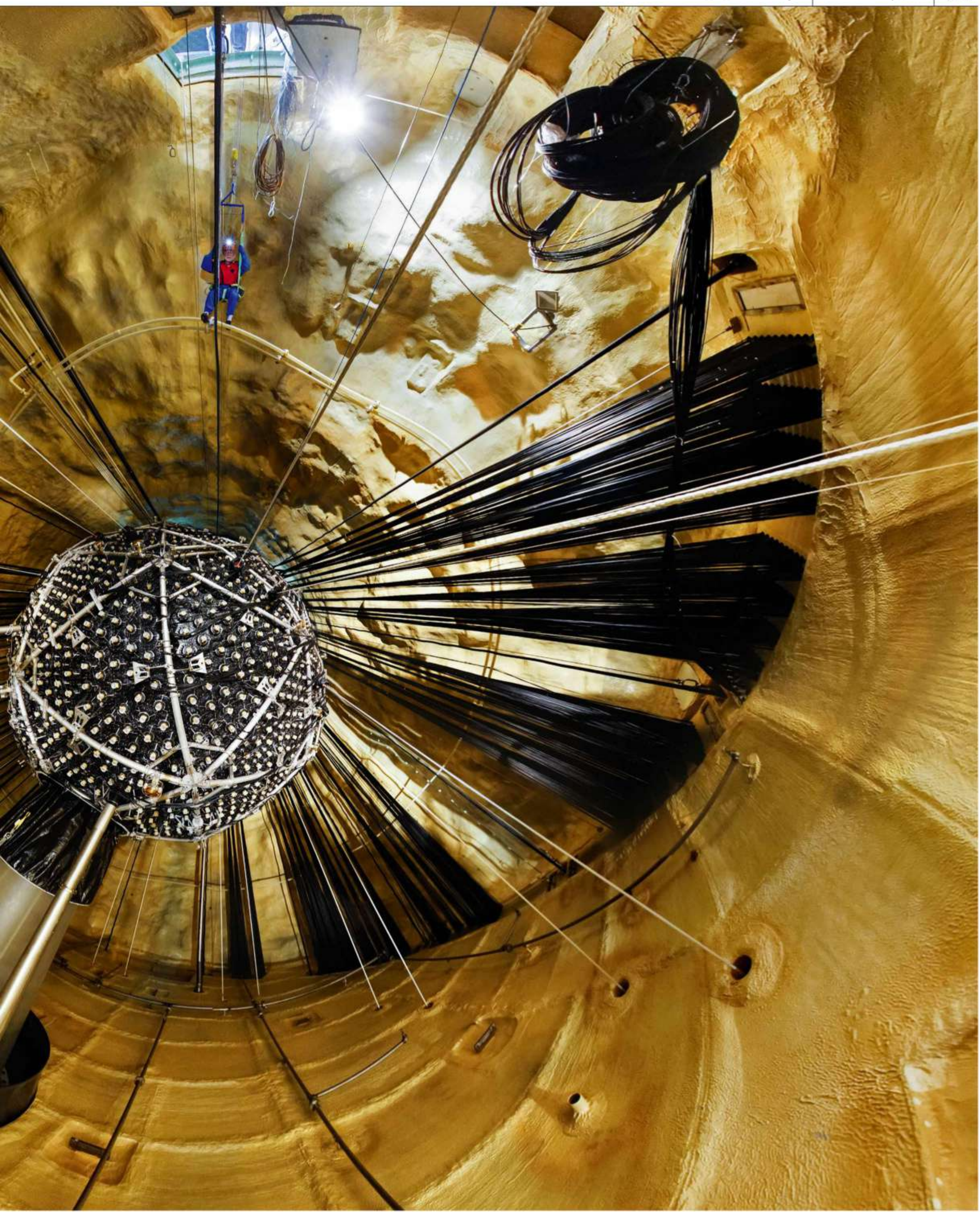
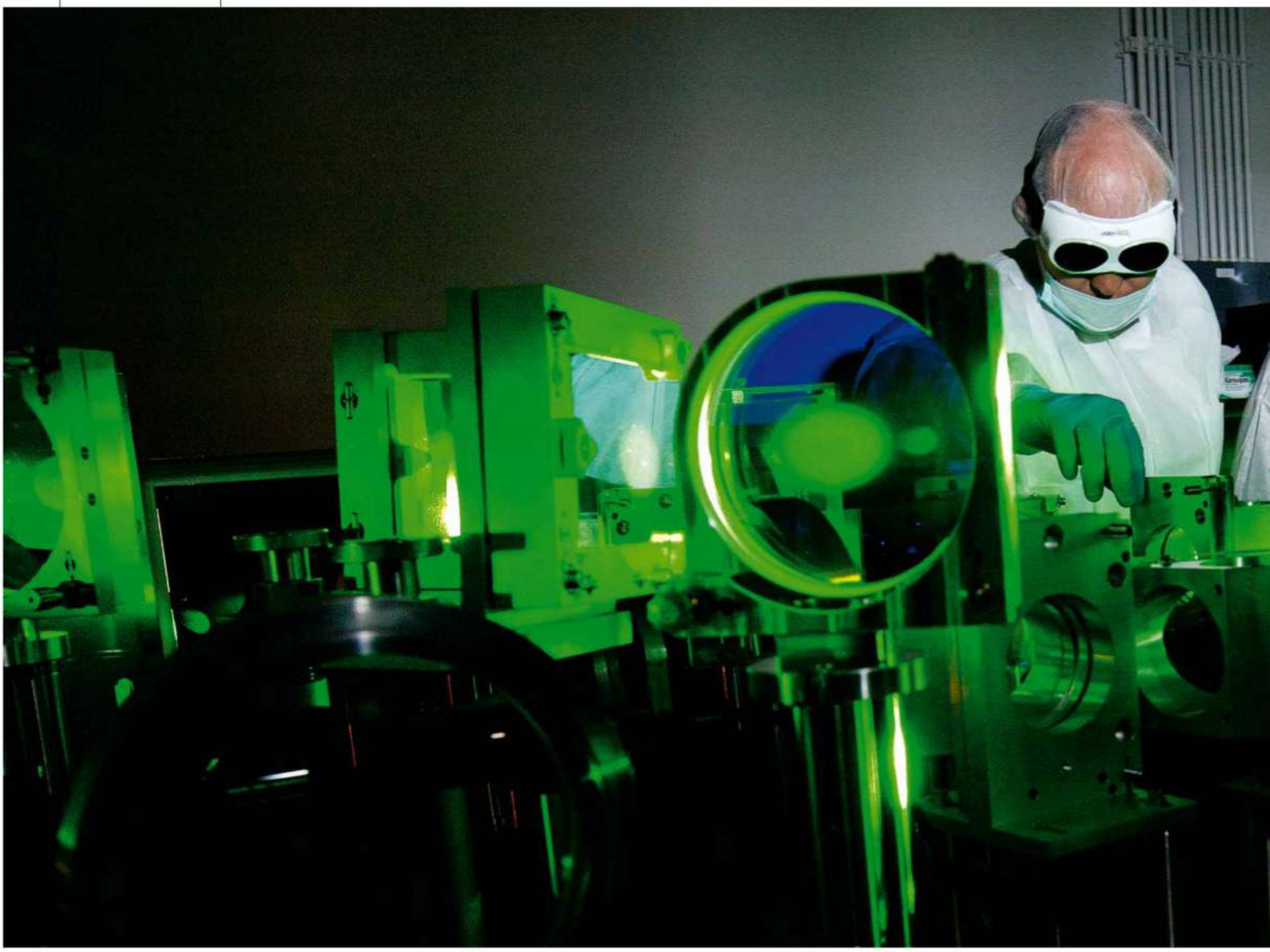
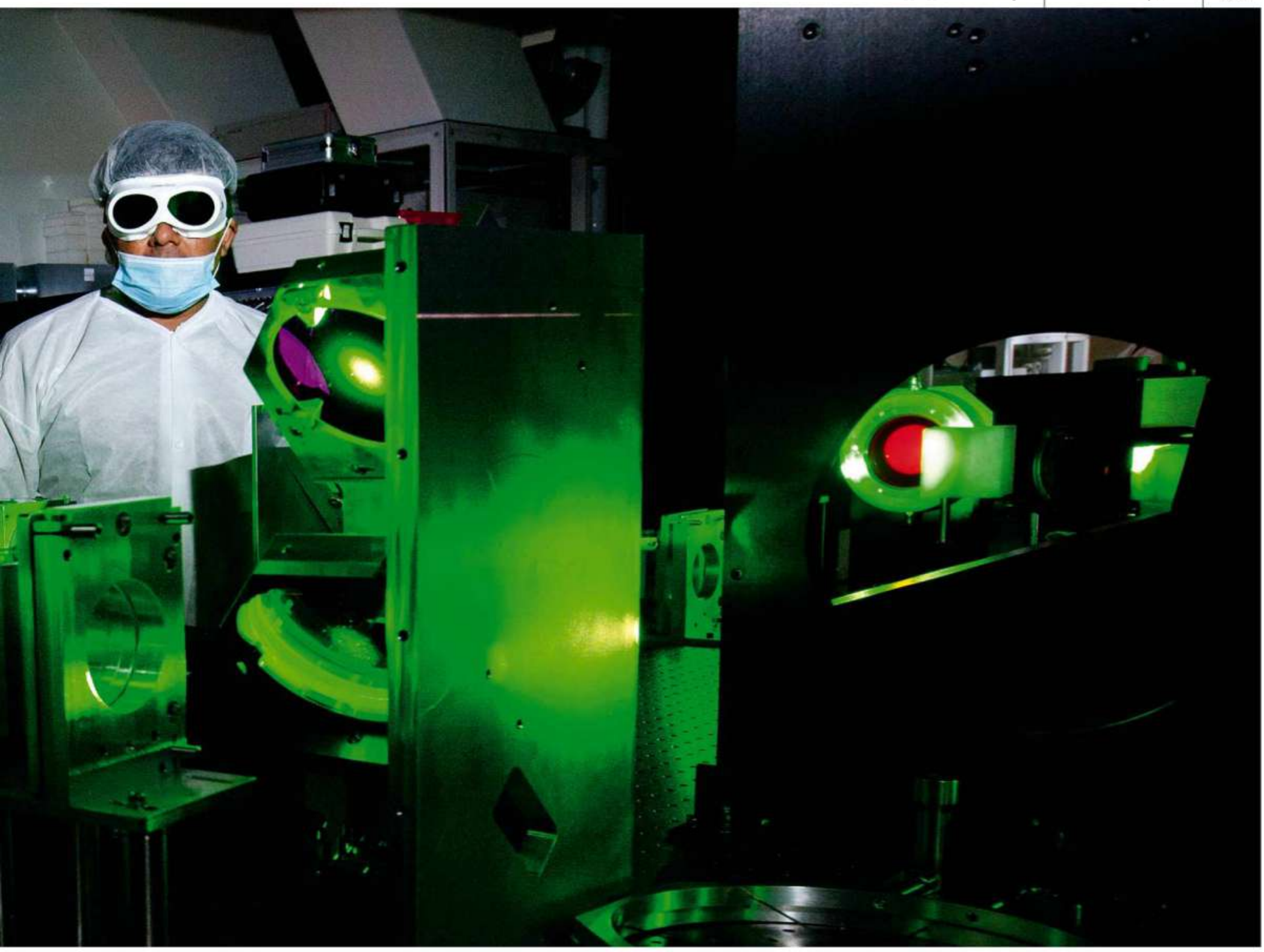




UNIVERSITY OF NEBRASKA-LINCOLN, NASA/GRC



←

THE LOUDEST

NASA REVERBERANT ACOUSTIC TEST FACILITY, OHIO, USA

Launching rockets is a noisy business, and scientists need to make sure that payloads can withstand the extremely loud sounds involved in take-off and ascent into space.

NASA's Reverberant Acoustic Test Facility carries out part of a suite of testing that complex and sensitive hardware must undergo before being deemed clear for take-off, by submitting them to noises of up to an eardrum-bursting 163 decibels.

In order to make the necessary sounds, NASA's Reverberant Acoustic Test Facility uses 36 huge horns, which are powered by the change in pressure as liquid nitrogen turns into gas. Each of the horns – which can produce volumes equal to thousands of home speakers – emit different frequency ranges, so the noise can be tailored to suit the necessary requirements.

↑

THE BRIGHTEST

EXTREME LIGHT LABORATORY, NEBRASKA, USA

Another lab that needs to keep an eye on its cleanliness is responsible for producing the brightest light ever known on Earth. The Extreme Light Laboratory at the University of Nebraska-Lincoln broke records in 2017 by generating a light a billion times brighter than the surface of the Sun. The light is produced by focusing a laser beam extremely intensely and then using it to bombard a single electron with short powerful laser pulses, each only a fraction of a second but with more power than a trillion light bulbs.

You might think such an extreme light would require a huge machine, but in fact the equipment is small enough to fit into an ordinary laboratory. Researchers wear safety glasses, hair nets and other protective clothing to keep the equipment safe from dust.

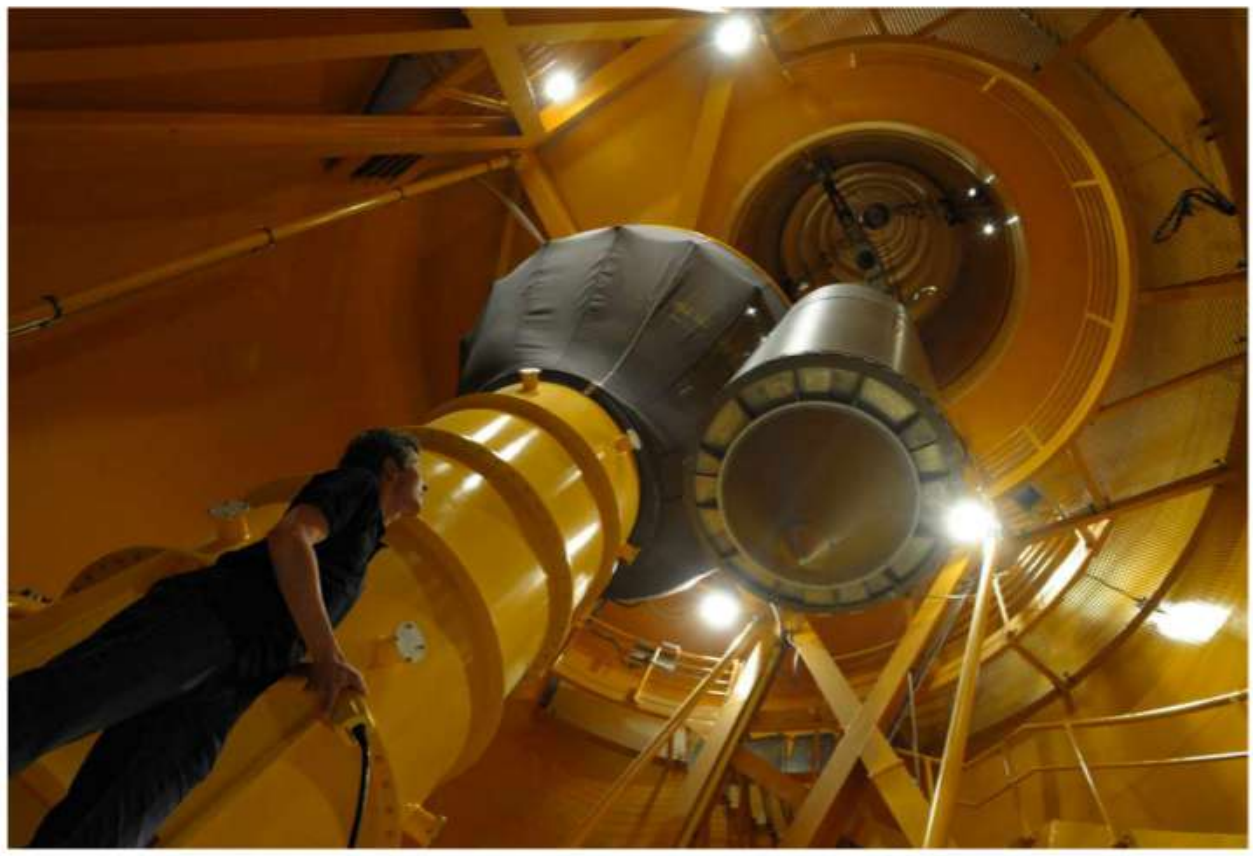
↑

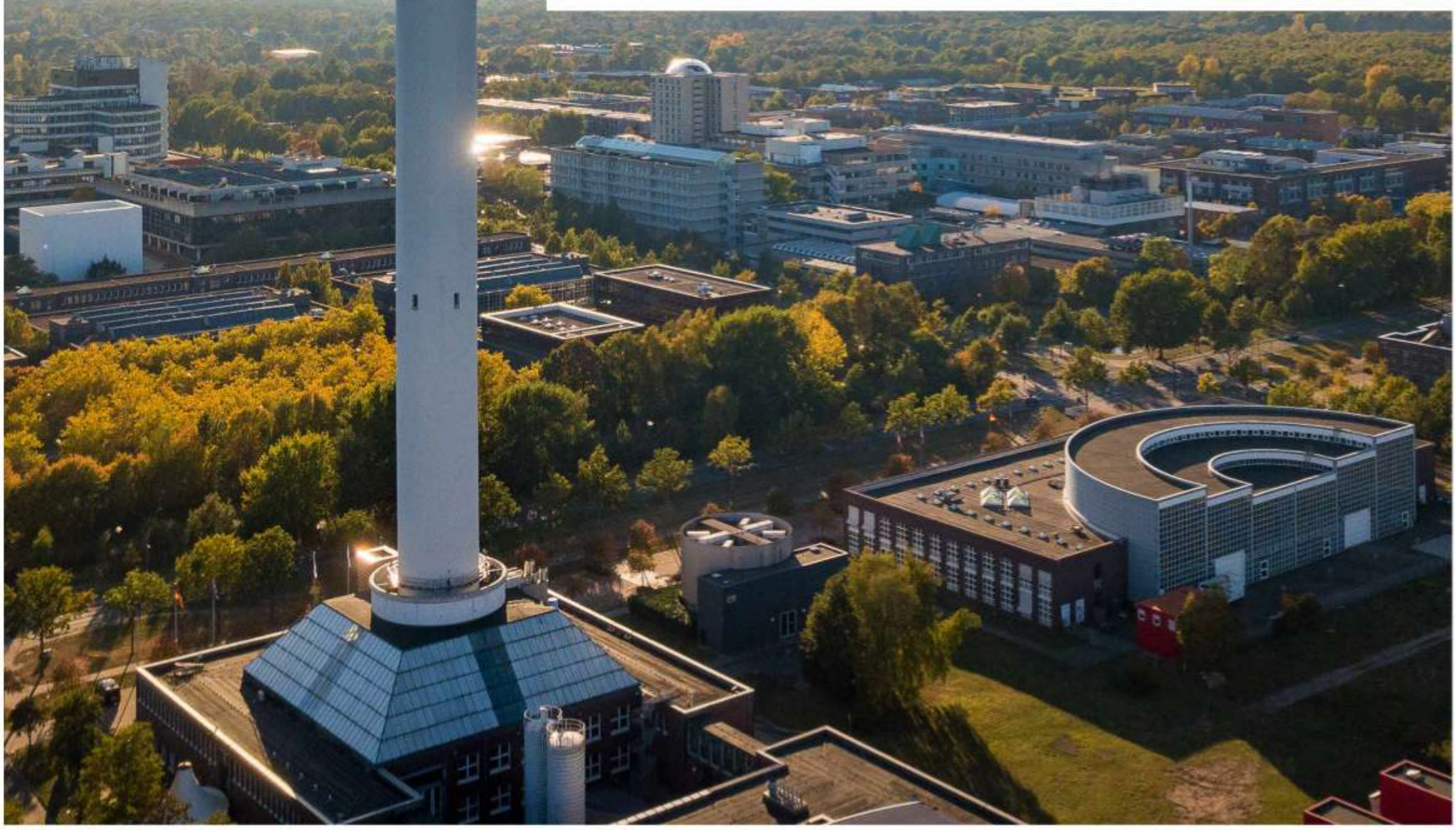
THE HIGHEST

PYRAMID LAB, KHUMBU VALLEY, NEPAL

Nestled in Nepal's Khumbu Valley, just over 5,000m above sea level in the Sagarmatha National Park, is the Pyramid Lab. Located 7.2km from Everest Base Camp, the 8.4m-high glass, aluminium and steel pyramid generates its own power from solar panels. The Pyramid Lab project was the result of a scientific race between two research teams – one American and one Italian – to establish whether Mount K2 in Pakistan was in fact taller than Everest. From the Italian collaboration came the idea of a research station to house high-altitude research and replace the tents and unreliable generators upon which researchers had previously depended.

The laboratory was opened in 1990 and has been used by hundreds of scientists to conduct high-altitude environmental, geological and health research. Sadly, funding for the lab was frozen in 2015, closing it to researchers and endangering the data from its varied environmental monitoring instruments.





GETTY IMAGES, ZARM/UNIVERSITY OF BREMEN X2

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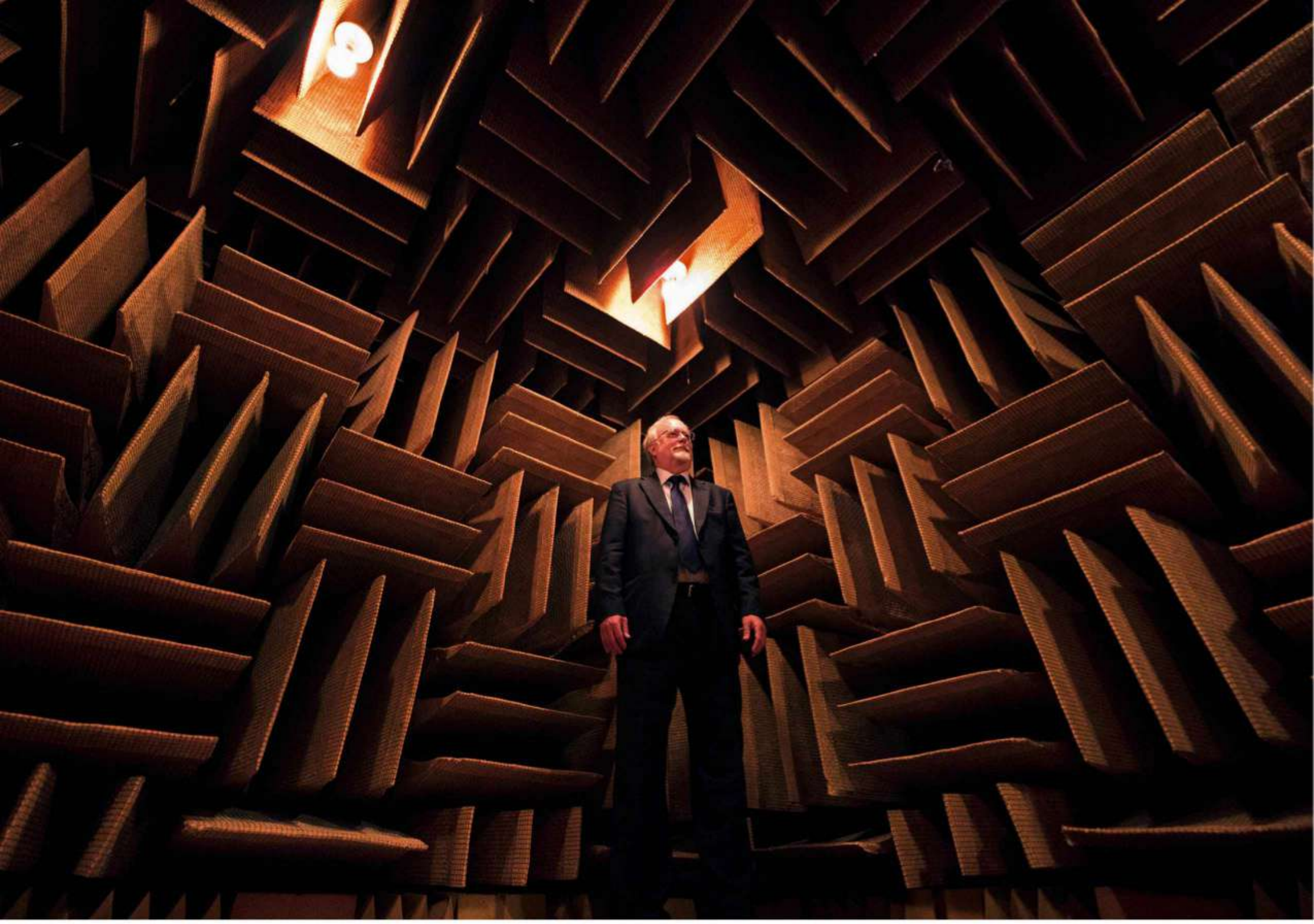
THE COLDEST

FALLTURM, BREMEN, GERMANY

Rising 146m above the University of Bremen, the Bremen drop tower, or Fallturm, looks a little like Rapunzel's tower. But its appearance hides some innovative machinery, used by scientists to perform near-zero gravity experiments by dropping them inside the tower to reach weightlessness. Some experiments focus on how equipment destined for space will perform, others use the lack of gravity to explore phenomena that are not detectable in normal gravity. One such project produces 'Bose-Einstein condensates', low-density clouds of gas that are cooled to near absolute zero. At such low temperatures, all the atoms coalesce and begin to act like a single atom, allowing researchers to study quantum mechanics. In 2021, researchers producing these condensates achieved a temperature 38 trillionths of a degree warmer than absolute zero, for a total of two seconds. Previously, the coldest temperature identified anywhere in the Universe was the Boomerang Nebula, located 5,000 light-years from Earth. At -272°C, it is 1°C warmer than absolute zero.



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THE QUIETEST

ORFIELD LABS, MINNEAPOLIS, USA

It's not unusual to long for peace and quiet, but some places can be *too* quiet. That's said to be the case for the Anechoic ('no echo') Chamber at Orfield Labs in Minneapolis, once dubbed 'the quietest place on Earth'.

Sealed off from the rest of the world by layers of steel and concrete, and lined with thick fibreglass shapes, the walls of the chamber absorb 99.9 per cent of sound. The chamber measures -9 decibels (around 0 decibels is the quietest sound a human can hear). It's a great place for manufacturers to test their products – how their loudspeaker is performing, or whether a new gadget makes too much noise, for example – but it's less great to hang out in. We're used to sounds reflecting off surfaces, so anyone in the chamber quickly becomes uncomfortable due to the eerie sound quality. In the absence of any other sounds, they begin to hear the functions of their own body – such as the blood pulsing in their brain – and can become disorientated without the usual auditory signals that root us in place.

by **KATHERINE NIGHTINGALE** *(@kathnightingale)*
Katherine is a freelance science journalist.

→

THE LARGEST

CERN, FRANCE/SWITZERLAND

The world's biggest laboratory is probably also the most famous: CERN. Housing the Large Hadron Collider (LHC), which was used to find the theorised Higgs boson in 2012 (a detection which bagged its discoverers a Nobel Prize), CERN's home in the countryside outside Geneva covers 550 hectares (1,360 acres) across Switzerland and France and is host to more than 12,000 scientists.

The LHC is also the biggest machine in the world. Located almost 100 metres below ground, its 27km ring of superconducting magnets works with a number of other structures to accelerate subatomic particles, colliding them into each other and monitoring the results in an attempt to recreate conditions of the Big Bang, and unlock the secrets of how the Universe was formed.

After a three-year break, during which time it was revamped to become more powerful and include more experiments, the LHC beam has just started up again, and scientists are excited to see what will be discovered next.

→

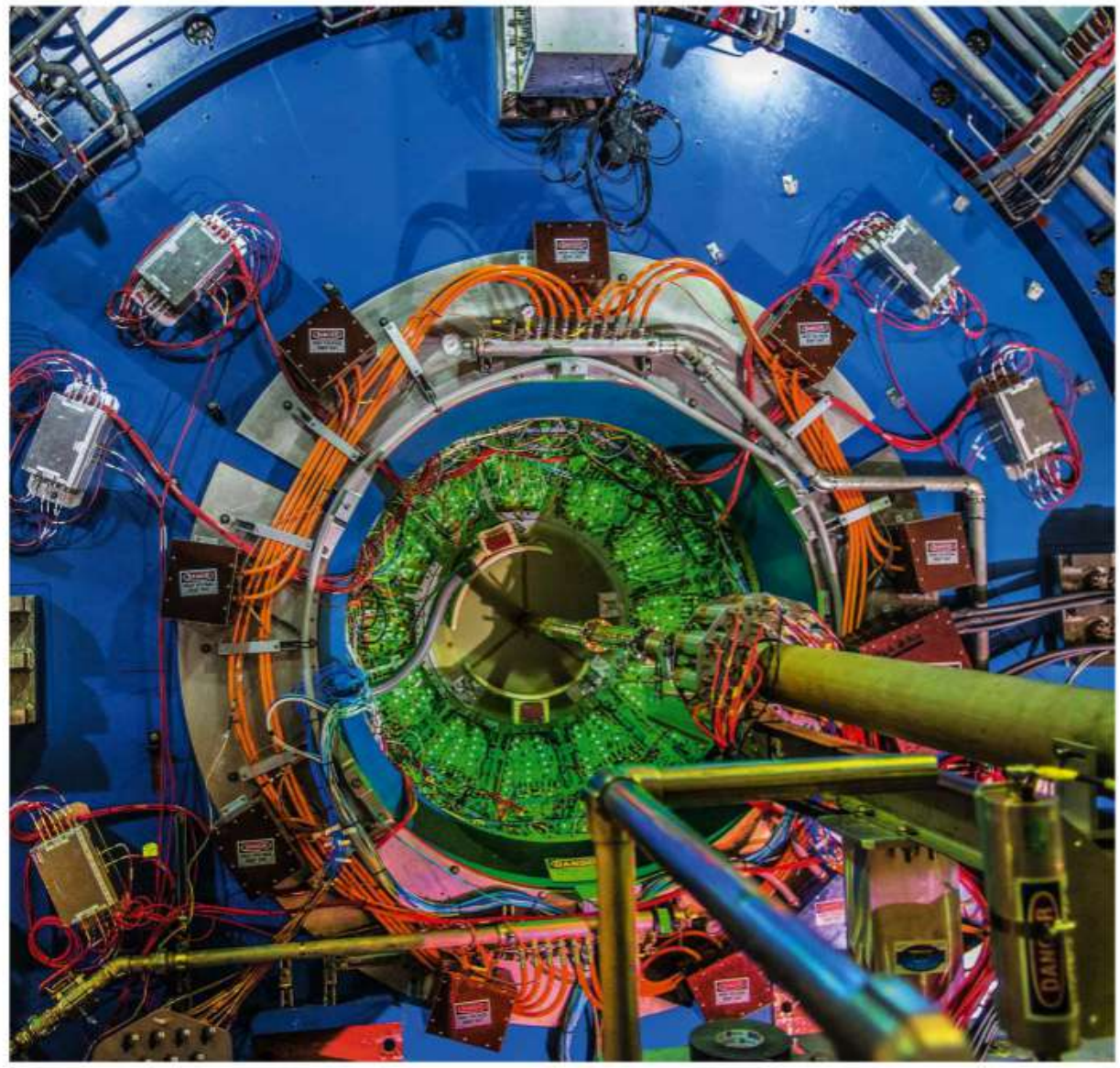
THE HOTTEST

RELATIVISTIC HEAVY ION COLLIDER, NEW YORK, USA

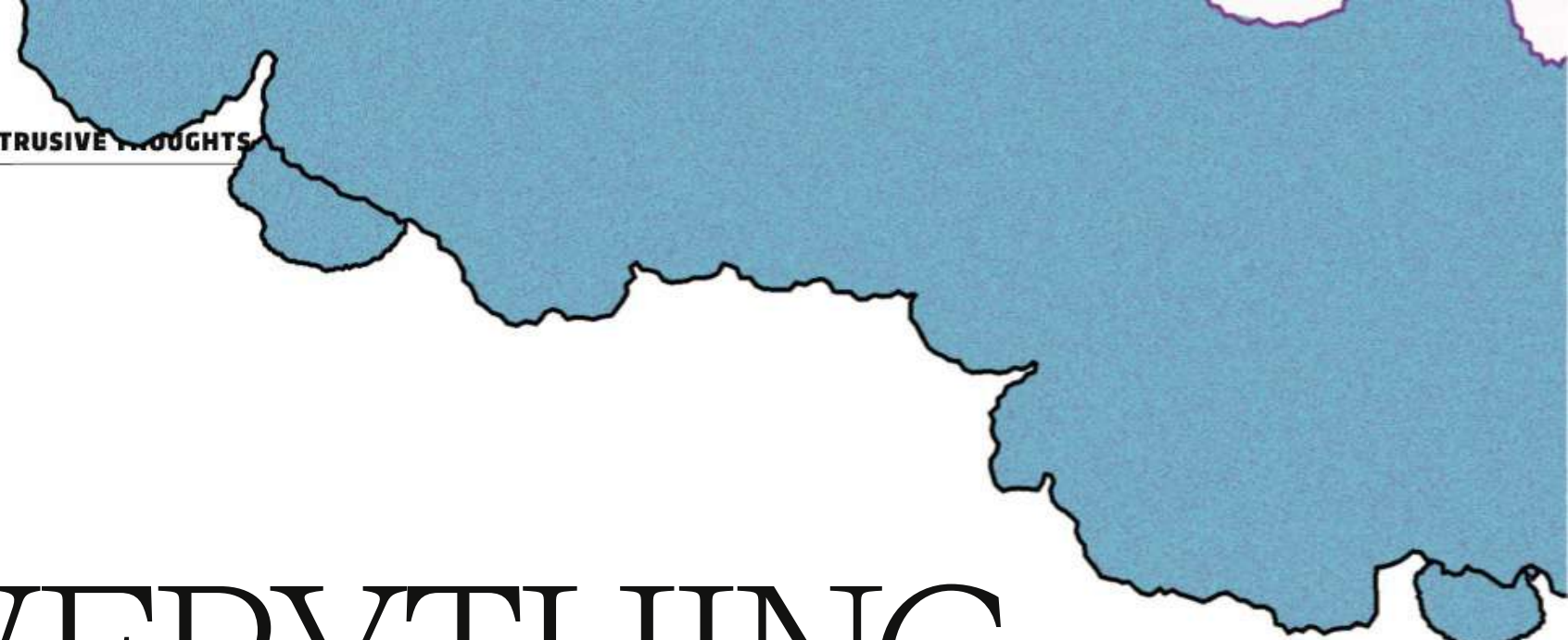
Sticking with colliders, researchers using the Relativistic Heavy Ion Collider (RHIC) at the Brookhaven National Laboratory in New York State have achieved the hottest temperature recorded on Earth.

The RHIC specialises in colliding larger, heavier particles such as gold ions (gold atoms which have lost electrons). By smashing gold ions into each other in the RHIC's 3.8km collider ring at near light speed, a temperature of four trillion degrees Celsius – about 250,000 times hotter than the middle of the Sun – was produced for a fraction of a second.

The collision 'melts' the protons and neutrons in the gold ions, releasing their component quarks and gluons and forming a quark-gluon plasma. But it's not just about breaking records. It is thought that this plasma filled the Universe shortly after the Big Bang, so studying it could tell us more about the Universe's first seconds. **SF**



ALAMY, BROOKHAVEN NATIONAL LABORATORY, CERN

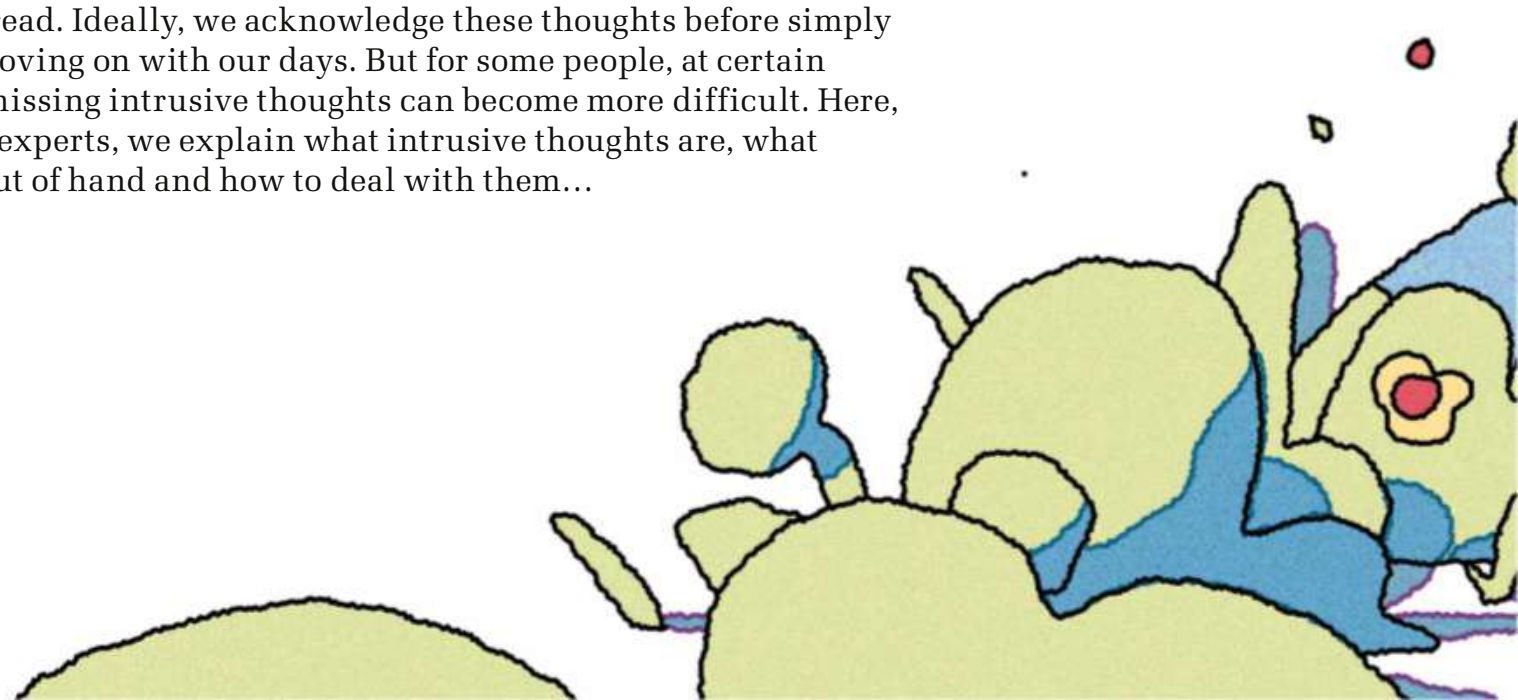


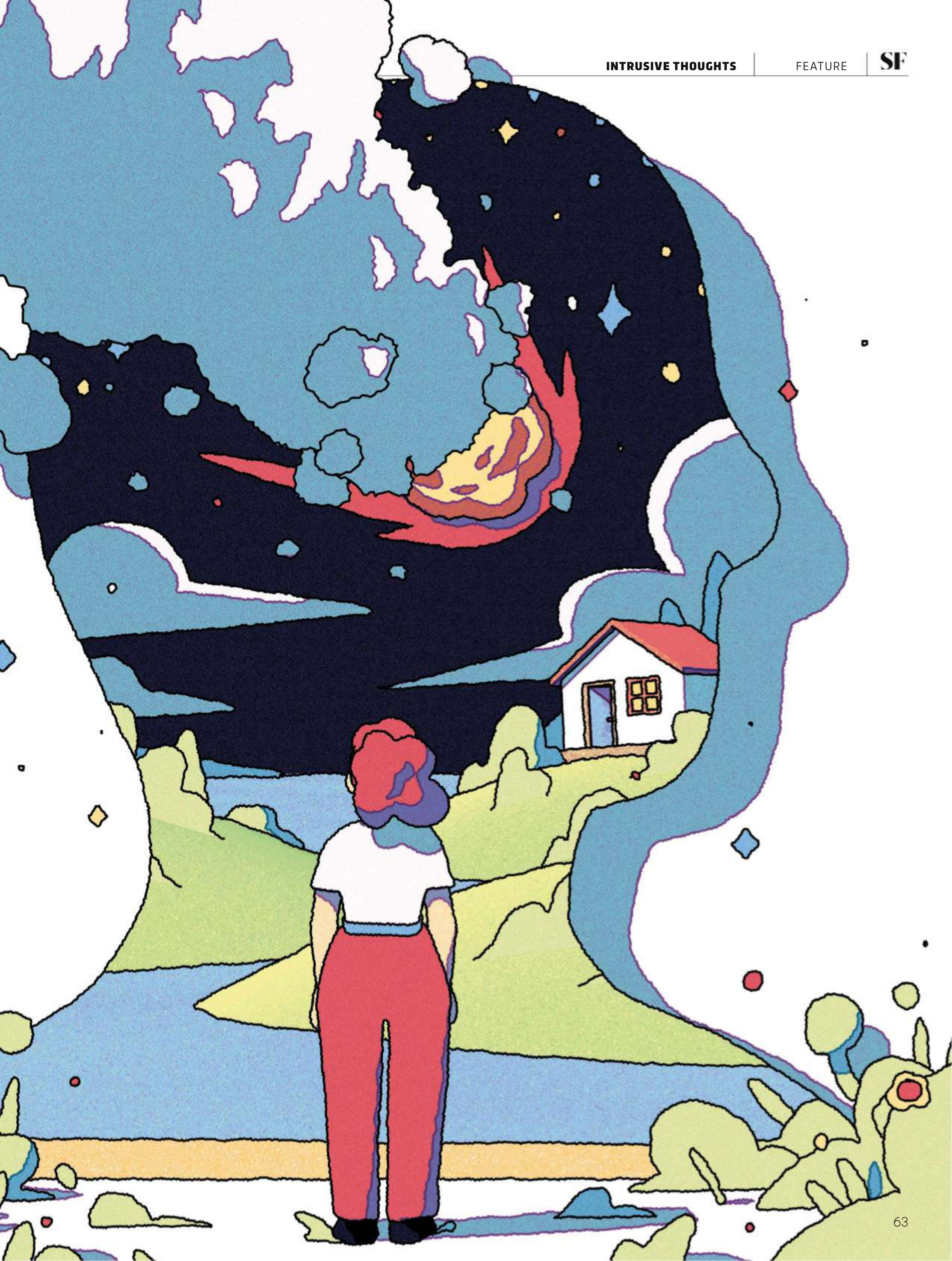
EVERYTHING YOU NEED TO KNOW ABOUT INTRUSIVE THOUGHTS

Occasionally, you're minding our own business when a weird – and sometimes disturbing or upsetting – thought pops into your head. Why does your brain do this, and does it mean that you're a bad person?

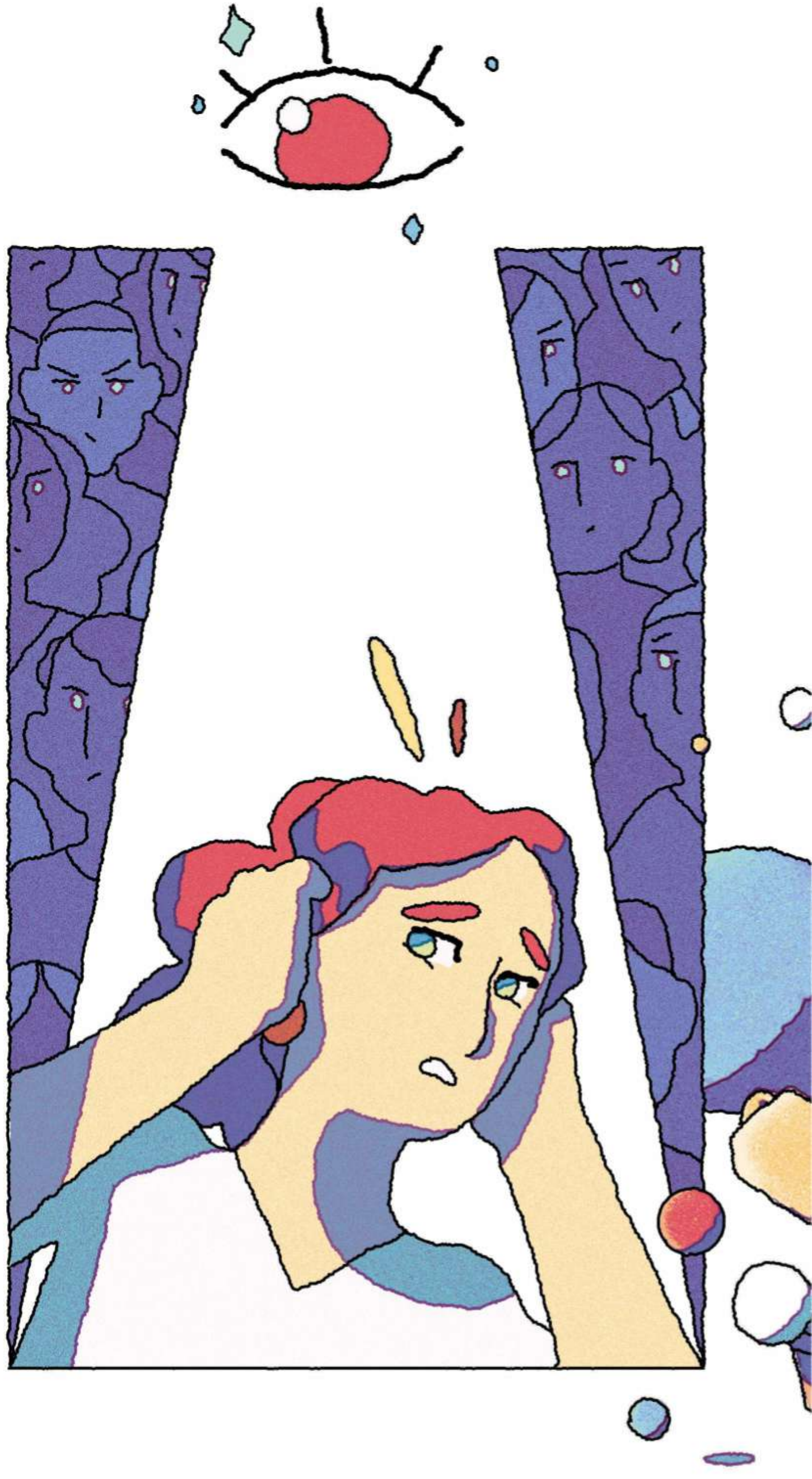
WORDS: HAYLEY BENNETT ILLUSTRATIONS: KYLE SMART

Have you ever been driving along a motorway, listening to the radio, when your brain suddenly piped up with, "Hey, what if I just turn into the central reservation?" Or perhaps you picked up a knife to slice some bread and wondered, "What if I was to hurt someone with this?" These are examples of intrusive thoughts – just thoughts that pop into your head, either of their own accord or maybe because of the situation you're in, such as driving a car or slicing bread. Ideally, we acknowledge these thoughts before simply setting them aside and moving on with our days. But for some people, at certain points in their lives, dismissing intrusive thoughts can become more difficult. Here, with some help from the experts, we explain what intrusive thoughts are, what happens when they get out of hand and how to deal with them…





WHAT ARE *INTRUSIVE* THOUGHTS?



From the broadest perspective, an intrusive thought is anything random that "pops into mind", says clinical psychologist Prof Mark Freeston, who specialises in obsessive compulsive disorder (OCD) and anxiety disorders at Newcastle University in the UK.

Technically, an intrusive thought could be positive, but it's more often than not the negative ones that we notice. An example might be a sudden panic that you've left the oven on and your home is going to burn down. The sort of thing that we all think about from time to time. We might not think of it as 'unwanted', because it's just a thought that we quickly forget about.

Then there are the intrusive thoughts that are very much unwanted, in mental health complaints such as OCD, post-traumatic stress disorder (PTSD) and social anxiety. "In social anxiety, the intrusive thoughts would likely be 'How are other people seeing me?', 'Is my hand shaking?'" says Freeston. Whereas, in OCD, the thoughts may be fears of contamination, or in PTSD, they may be memories or flashbacks of a traumatic event.

In psychology, what marks out an intrusive thought as different to a worry or other type of thought is that it's at odds with what you generally believe to be true, or your values. Psychologists refer to this as an 'egodystonic' thought. Worries are considered more 'egosyntonic', meaning they're more aligned with our beliefs. For instance, if you have been reading about the rising costs of energy and supermarket essentials, and are starting to spend more than you earn, you might understandably be concerned about how you're going to pay your bills, but that would be a worry – not an intrusive thought.

ARE *INTRUSIVE* THOUGHTS NORMAL?

Yes, although we didn't always realise this. Psychologist Prof Jack Rachman was the first to show experimentally that intrusive thoughts are 'normal'. In the 1970s, he and colleague Padmal de Silva surveyed 124 people with no known psychiatric conditions and found that nearly 80 per cent of them often had thoughts that would be classed as intrusive. They compared the content of these thoughts to those of people being treated for obsessions. Surprisingly, when the intrusive thoughts experienced by both groups were written down, a panel of psychologists found it difficult to work out which group a lot of them belonged to. There were differences though. In clinical patients, intrusive thoughts tended to crop up more often; they were also more intense and harder to dismiss.

While Rachman's study profoundly influenced the next half a century of research on intrusive thoughts, the data on which it was based was from a relatively small group of UK students. Researchers carried out similar surveys over the years, but they were still limited to Europe and the US. Then, in 2014, a multinational team of researchers looked further afield, studying intrusive thoughts in 777 people across 13 countries and six continents. The team interviewed each person to check that they were really having intrusive thoughts as opposed to worries or other types of thoughts. The results suggested that 94 per cent had had at least one intrusive thought in the previous three months.

Today, Prof Adam Radomsky, the lead author of the 2014 study, who is based at Concordia University in Montreal, Canada, says he believes we all have intrusive thoughts. "We know that people are more likely to notice them or struggle with them during stressful periods," he says. "But I think it's just a fact of humanity that we have them. Most of them we probably don't notice."

Perhaps the fact that we do have them is the result of important processes going on in our brains – if we never had random thoughts or considered things that we didn't believe to be true, how would we create abstract art or dream up fantastical fictions? Freeston agrees that intrusive thoughts are "part of the human condition", adding that it's beneficial for humans to have random thoughts popping up all the time. "One of the arguments that has been put forward is that if we didn't have random thoughts, we would never solve problems," he says.

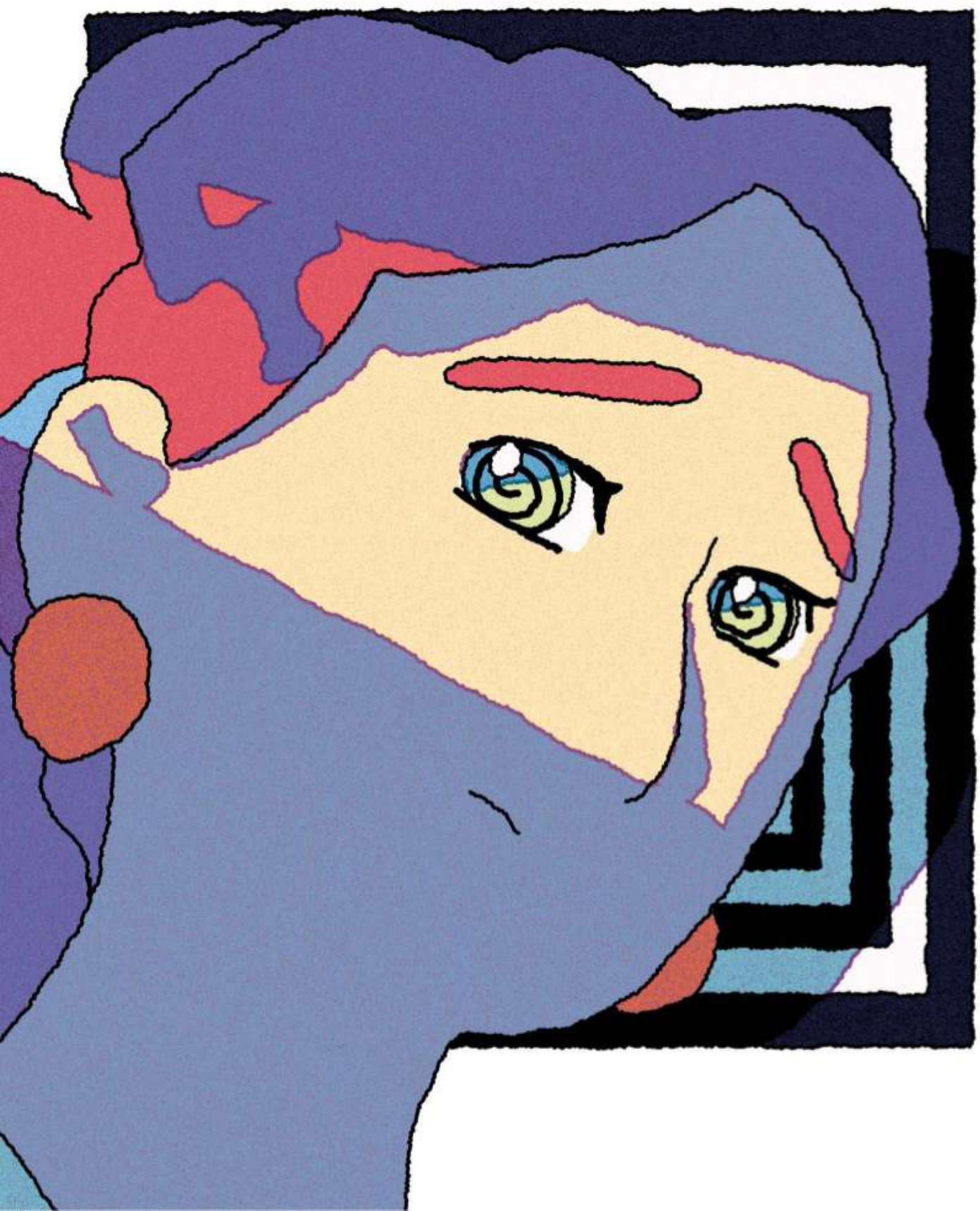
In OCD, the relationship between intrusive thinking and creativity has been explored as a way of confronting the condition head-on. For instance, writing down random thoughts could be a way to harness them instead of allowing them to block up our brains.

HOW WILL I KNOW IF MY *INTRUSIVE* THOUGHTS ARE A PROBLEM?

It's how you respond to the intrusive thoughts that tends to determine whether they're problematic. "Someone could have a thought about some bizarre, evil thing happening," says Freeston. "If you were Stephen King you'd say, 'That's a great idea.' And then write a novel. But if you think, 'What sort of a person has this bizarre thought?' or 'It might mean that I'm this awful person that I think I am', from there, an intrusive thought could become an obsession."

Obsessions in the clinical sense are intrusive thoughts that are unwanted and repeated often. These can develop in OCD, particularly in OCD that occurs during pregnancy or after childbirth. But repeated, unwanted thoughts are also characteristic of a raft of other mental health conditions, from PTSD and eating disorders to schizophrenia. Intrusive thoughts can also be related to physical health problems. Cancer patients, for example, can suffer intrusive thoughts about their cancer returning that may impinge on their physical recovery.

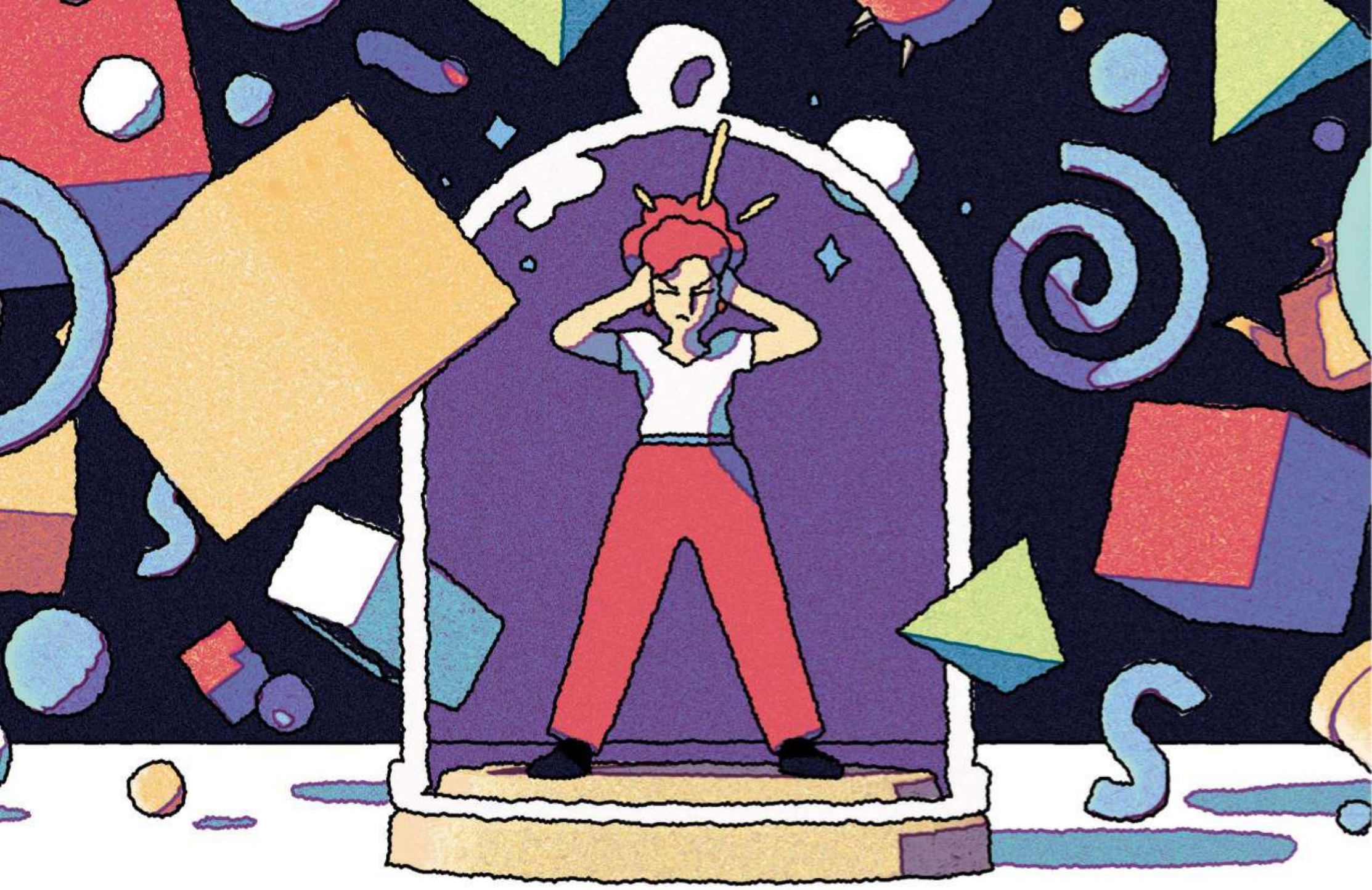
In people who develop obsessions or more distressing intrusive thoughts, the thoughts begin to occur more regularly when they try too hard to get rid of them, instead of just accepting and ignoring them. In some cases, people progress to carrying out physical actions to try to deal with the thoughts, such as tapping, counting or repeatedly checking that they've performed a particular task. These are compulsions.



If you're going through a particularly busy or stressful period and noticing yourself struggling with intrusive thoughts more than normal, this doesn't necessarily mean you're developing OCD. It just means you need to be more mindful and perhaps do things to help you reduce the stress. Radomsky suggests "not necessarily pushing the thought out or avoiding it, but focusing on the things that matter," along with some self care, which might be as simple as sleeping and eating well.

On the other hand, intrusive thoughts that come out of the blue need to be taken seriously. Abrupt onset of OCD symptoms in children might be the result of a bacterial or viral infection, as in Paediatric Acute-onset Neuropsychiatric Disorders Associated with Streptococcal infections (PANDAS). First described in the 1990s by child psychiatrist Dr Susan Swedo, PANDAS is rare, so can still be thought of as a controversial diagnosis, according to Alison Maclaine, whose 12-year-old son Jack developed PANDAS over four years ago. Jack now struggles to leave his room due to intrusive thoughts about dying and running away. "The intrusive thoughts were one of the first symptoms of his illness and have consistently been the cause of most distress," Maclaine says. "For the last five months, he has been unable to attend school."

Jack's intrusive thoughts were initially put down to autistic spectrum disorder and anxiety. Eventually, he was treated with anti-inflammatories and antibiotics, which helped, but Maclaine wonders how different life would be now if they had received the correct diagnosis straight away. (Other symptoms that may indicate PANDAS are tics, hyperactivity, problems sleeping, and panic or rage attacks.)



WHAT CAUSES THE *INTRUSIVE* THOUGHTS?

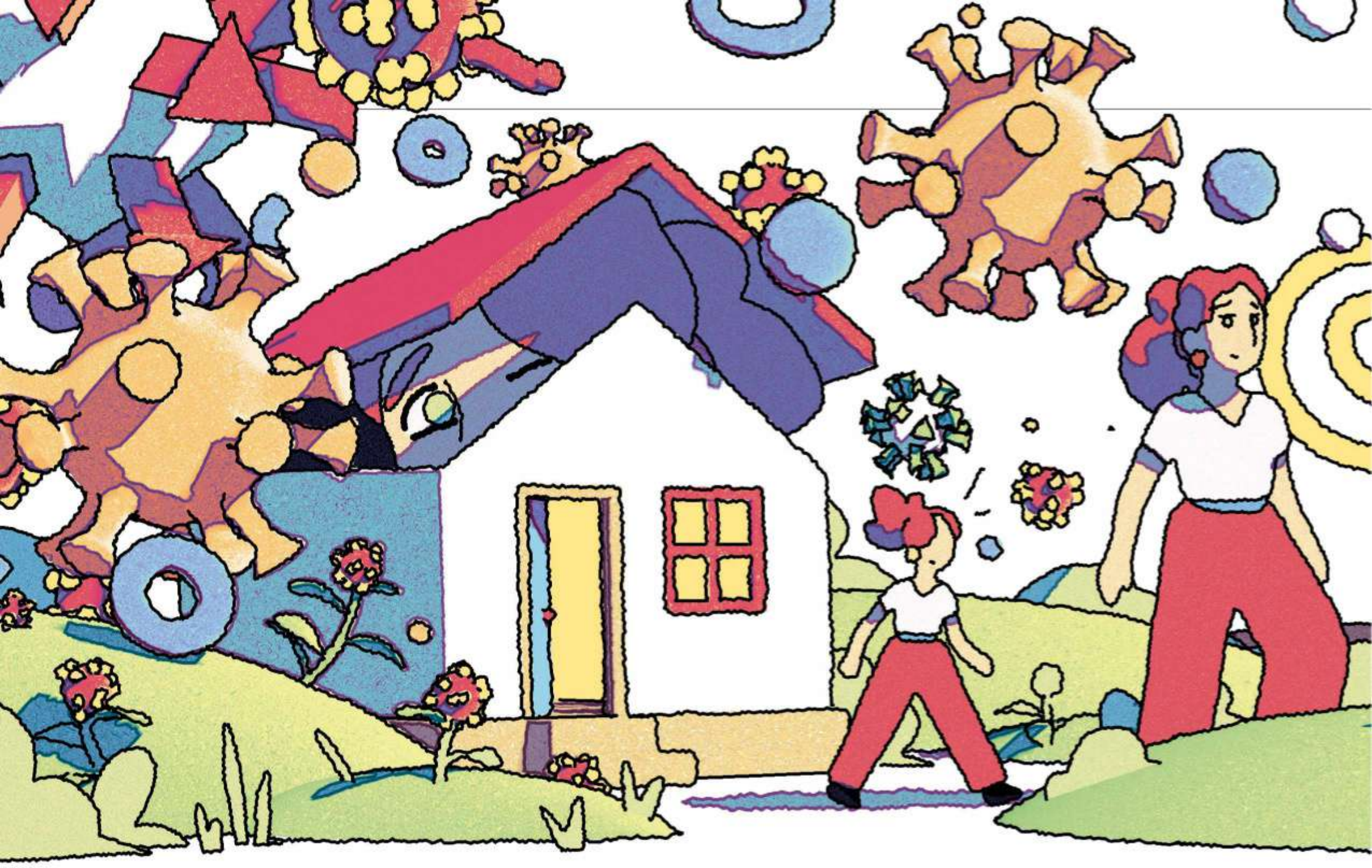
Remember, intrusive thoughts are normal. If we accept that they're just random thoughts, then what causes them is simply the constant bubbling-up of ideas and memories in our busy brains. According to Radomsky, there is sometimes a trigger for such thoughts – seeing a fire extinguisher, for example, and then finding yourself wanting to rush home and check that the house hasn't burned down. But sometimes they really are random; just the result of our minds being 'noisy'.

What about those people whose intrusive thoughts bother them, though? Do their brains work differently? Perhaps they do. In 2020, Portuguese researchers reviewed evidence collected over the last decade concerning people with OCD and how they regulate their thinking – what happens, for example, when they're asked to focus on unpleasant mental images or real pictures. The researchers found that in brain scans, people with OCD show "altered brain responses" across several areas of their brains compared to healthy volunteers.

This brain imaging may just be illuminating what psychologists describe as someone trying to push away their thoughts. For his part, Randomsky doesn't favour neurobiological explanations for why people struggle with intrusive thoughts, because he doesn't believe they're helpful when it comes to treating them. "There's very little we can do to change the brain directly," he says. "But we do have complete control over what we choose to think and what we choose to do, so there's a lot more potential to talk about the mind and behaviour instead of talking about the neurobiology."

By talking to people, psychologists can sometimes identify reasons why individuals might be sensitive to the content of certain intrusive thoughts – perhaps as a child they witnessed a fire or a violent attack. Later in life, there are times when we're all supersensitive to certain thoughts and, hence, we're more likely to take notice of them. After becoming a parent, for instance, we might be hyperaware of safety issues.

But although we might think of these sensitivities as 'causes', rather than any structural or chemical differences in the brain, whether someone develops OCD is partly just down to bad luck, according to Freeston. "Potentially there has been a series of times when you've been particularly vulnerable and you've had a thought and you've appraised it in a particular way," he says. "So ultimately, the reason why you got OCD is none of these initial causes. It's this combination that means that you ended up appraising the thought in a particular way, acting on that and then strengthening your system of appraisals and behaviours over time."



WHAT IF MY *INTRUSIVE* THOUGHTS ARE REAL?

Remember that intrusive thoughts tend to be at odds with people's actual beliefs or values. So a person with an eating disorder may have intrusive thoughts about being overweight, even if they can agree, when looking at a number on a scale, that they're not.

By the same token, a person with OCD may have intrusive thoughts about something bad happening because they've been contaminated by germs or particular items aren't ordered in a certain way. And those thoughts may still bubble up even if that person can rationally say that nothing bad is likely to happen.

Sometimes, however, real-life events occur that can confuse matters. Such as when a pandemic breaks out, for example. Disease outbreaks are known to temporarily increase intrusive thoughts about illness and in the world we've lived in for the last two years, contamination of every available surface and air space is a legitimate concern.

So if you have intrusive thoughts about virus-contaminated surfaces or catching COVID, is it something to be concerned about? Prof Meredith Coles, director of the Binghamton Anxiety Clinic at Binghamton University, New York, ponders the question. "In some respects, I could argue that your anxiety should have been elevated in the last year or two – that you should have been having more intrusive thoughts," she says, adding that a bit of anxiety may not be a bad thing if it motivates you to get vaccinated. "Does that mean you have OCD? Or does that mean you're human and you're going through a pandemic?"

We've certainly all been through a difficult time. But what about those of us who are already suffering from OCD. Could COVID exacerbate the condition? One Italian study published in 2021 suggested that it could.

For the study, 742 people completed questionnaires and the respondents who scored highly on washing and contamination questions normally used in OCD diagnosis tended to perceive COVID as more dangerous. However, a high score for health anxiety (previously referred to as hypochondria) was more strongly associated with concern about COVID.

Coles reckons that as we pass the peak of the pandemic, we should see any rise in intrusive thoughts receding. We're more resilient than we sometimes believe, she says. Though she does advise doing things to stay on top of our anxieties, such as seeking support from friends and family, and turning off the news once in a while.

HOW CAN I ***STOP*** MY INTRUSIVE THOUGHTS?

Again, intrusive thoughts are normal, so you can't stop them. But if intrusive thoughts are troubling you, then well-established treatments are available. For OCD (and body dysmorphic disorder), this is usually cognitive behavioural therapy (CBT) and exposure and response therapy, although there are separate, tailored CBT approaches for other disorders like PTSD. CBT focuses on helping you to change the way you think, including how you react to intrusive thoughts. Exposure and response therapy challenges you to confront the object of your fear, so if you have cleaning compulsions, it might involve touching the taps in a public toilet without carrying out ritual cleaning.

Although these treatments don't benefit everyone to the same degree, what benefit they do offer is backed up by strong evidence. There are also other new approaches, like mindfulness and compassion-focused therapy (which encourages patients to develop a more self-supportive inner voice), but they don't yet have the data behind them. "There's evidence that [they] work better than nothing, but there are very few direct comparisons," Freeston says, referring to how they compare with the standard approaches.

Developing new treatments also involves learning more about what causes intrusive thoughts. Coles is currently working on the relationship between sleep disturbances and intrusive thoughts in OCD. "People with OCD tend to stay up really late," she says, "It's just initial data, but this seems to potentially be related to not being able to get the thoughts out of your head."

Radomsky's group is working on helping people to change certain beliefs that might be related to their intrusive thoughts. For instance, the belief that their memory might not be very good; correcting that can help people get on top of repetitive checking behaviours. Another focus is beliefs about losing control. "People believe sometimes that if they lose control of their thoughts, they might lose control of their behaviour," he says. "Those beliefs in OCD are inevitably false."

For anyone who feels that intrusive thoughts may be becoming a problem, he recommends *The Anxious Thoughts Workbook* by David A Clark. **SF**

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by **HAYLEY BENNETT**

Hayley is a science writer based in Bristol, UK.

LIFE AS WE KNOW IT

When the asteroid smashed into Earth 66 million years ago, it wiped out the fiercest, strongest creatures on Earth – the dinosaurs. So how exactly did our tiny, furtive ancestors thrive in the aftermath of an apocalypse?

by **PROF STEVE BRUSATTE**

ILLUSTRATION: MAGIC TORCH

ABOVE LEFT
The supercontinent Pangaea began to break apart in the early Jurassic, around 200 million years ago

ABOVE MIDDLE
When the asteroid smashed into Earth some 66 million years ago, as visualised here, it altered the path of evolution for the planet's species

ABOVE RIGHT
Illustration of the Chicxulub crater, located off the coast of modern-day Mexico, shortly after impact

During the Triassic, some 225 million years ago, two types of animals went their separate ways. They were both born on the supercontinent of Pangaea, the single slab of land that stretched from the North Pole to the South. Their fates would be different, but forever intertwined. One group was destined for grandeur, and before long, their aeroplane-sized bodies thundered across the land. Dinosaurs. The other group was relegated to the shadows to bide their time. Mammals. Us, our distant ancestors.

Fast-forward some 160 million years, through the Jurassic and to the end of the Cretaceous. Temperatures spiked and crashed, sea levels rose and fell, and the supercontinent became the many continents of today. Through all of this time, dinosaurs and mammals lived together, but followed their own paths. No mammal ever got larger than a badger, as they were held in check by the dinosaurs. Conversely, the smart and furry little mammals kept dinosaurs from the small-bodied niches, so there never was a miniature *T. rex* or *Triceratops*. Like ships passing in the night, the dinosaurs and mammals both diversified, claiming separate realms as their own. Dinosaurs ruled the forests and plains by day, mammals the brush and underground in darkness.

Then, in an instant, everything changed. Sixty-six million years ago, a sudden disaster reshaped the world, and within days, months and years, it upended an evolutionary status quo that had persisted for more than 100,000 millennia. The dinosaurs – except for a few peculiar species with wings and feathers, which became today's birds – couldn't cope, and they went extinct. Many mammals felt the pang of death, too, but some managed to endure. From these plucky survivors, the next great dynasty of Earth history would blossom.

DINOSAURS DIE, MAMMALS SURVIVE

With no hint of hyperbole, what happened 66 million years ago was probably the worst single day in the history of our planet.

As herds of *Triceratops* awoke and began their breakfast of ferns, they had no idea that an asteroid the size of Mount Everest was on a collision course with Earth. It darted through the heavens faster than a gunshot,

GETTY IMAGES, SCIENCE PHOTO LIBRARY, ALAMY

"SHOCKINGLY, NEW RESEARCH SHOWS THAT MAMMALS NEARLY WENT THE WAY OF THE DINOSAURS"

and by the dumb luck of the cosmos, smashed into what is now the Yucatán Peninsula of Mexico, detonating with the force of over a billion nuclear bombs, punching a hole in the crust over 160 kilometres (100 miles) wide. Earthquakes ravaged the land and tsunamis sliced up the coasts, the atmosphere turned into an oven, forests spontaneously combusted, pellets of molten rock rained down from the sky. The soot and the grime coagulated in the atmosphere, turning the world dark for many years. Then, in a final insult, the carbon dioxide liberated by the impact superheated the Earth for millennia.

The effects of these immediate, medium-term, and long-term catastrophes was nothing short of an apocalypse. Ecosystems collapsed like houses of cards. Three out of every four species died, making this end-Cretaceous disaster one of the five biggest mass extinctions in Earth history. The most famous victims were all of the non-bird dinosaurs; monsters like *T. rex* would never stalk the Earth again. Also departing were the pterosaurs (flying reptiles) and the many reptiles, like plesiosaurs and mosasaurs, which swarmed the oceans.

All mass extinctions – at least so far – have had survivors. And this time, they were the mammals. Shockingly, new research shows that mammals nearly went the way of the dinosaurs: only about 7 per cent of species are thought to have made it through the fire and brimstone. Consider a game of asteroid roulette: a gun, with 10 chambers, nine of which hold a bullet. Take your shot: those survival odds are even better than what our ancestors faced at the end of the Cretaceous.

This raises the question: why were some mammals able to endure when the dinosaurs, and most mammals, were not? When comparing mammals to dinosaurs, the answer ➤

"TODAY, PLACENTAL MAMMALS ARE ASCENDANT. THERE ARE MORE THAN 6,000 SPECIES, WHICH TOGETHER MAKE UP ABOUT 95 PER CENT OF ALL MAMMALS"

ABOVE
Monotremes, the mammal group that includes the duck-billed platypus and echidnas, are the only surviving egg-laying mammals

RIGHT TOP
Gastornis, a large flightless bird, hunting a *Leptictidium*, a small mammal. *Leptictidium* lived around 50-35 million years ago and was widespread throughout Europe

RIGHT BOTTOM
The mammals that survived the asteroid impact were small and could eat many different foods, giving them the edge to survive and diversify in a post-apocalyptic world

seems straightforward. Most dinosaurs were large, it took them a long time to grow from baby to adult, and they had highly specialised diets focused on a few particular types of food. These were all liabilities when the world turned to madness. The surviving mammals, however, were drastically different, as shown by the research of Prof Gregory Wilson Mantilla and colleagues. These mammals were smaller than both the dinosaurs and the mammals that died, so they were able to hide easier, and maybe grow and reproduce faster. They had generalist diets, so they were not handicapped by reliance on one particular food source, but could eat whatever was on offer.

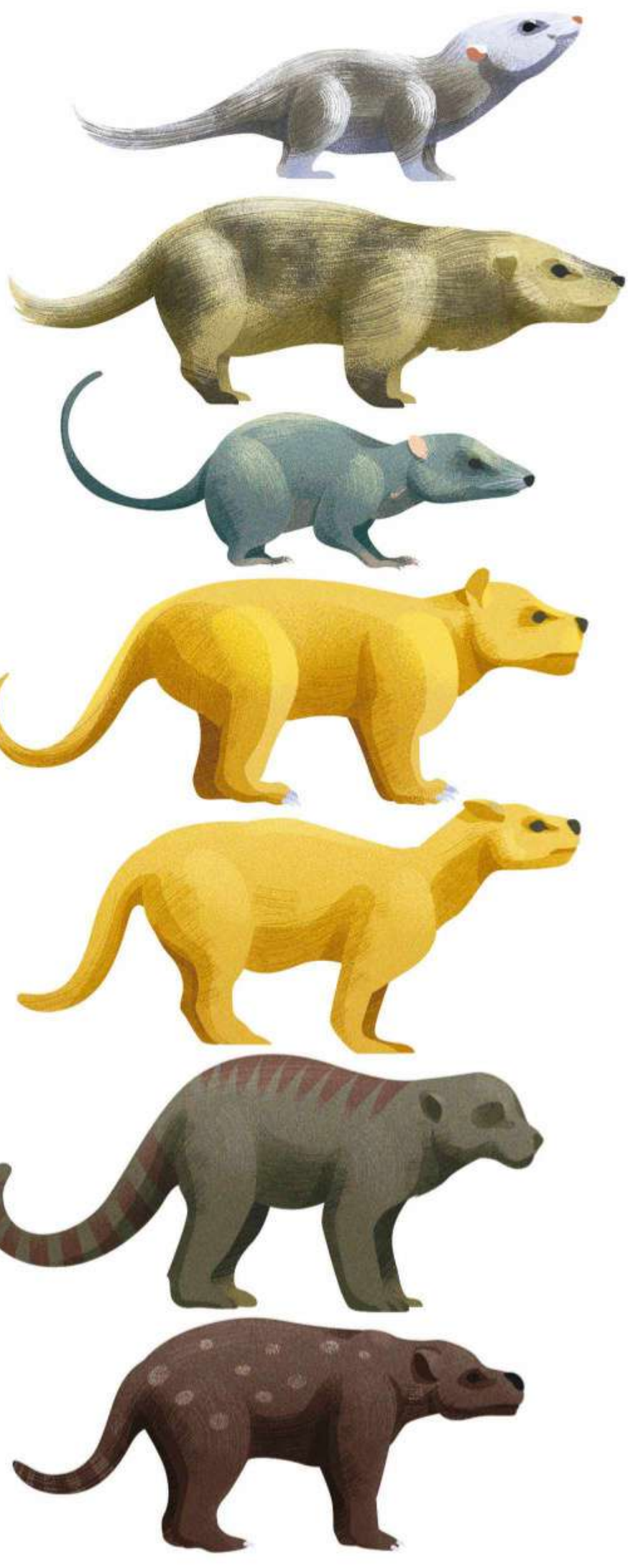
It's as if survival was a game of poker – part luck, part skill. The dinosaurs had a terrible hand of cards – the dead man's hand. Some mammals did too, particularly early relatives of marsupials (today's mammals that raise their tiny babies in pouches), which were common in the Cretaceous but then were nearly extinguished by the asteroid. Other mammals, however, had a much stronger hand of cards, and it was their ticket to a new future. The vast majority of these mammals were placentals: species that give birth to live, well-developed young.

THE PLACENTAL TAKEOVER

Today, placental mammals are ascendant. There are more than 6,000 species, which together make up about 95 per cent of all mammals. By comparison, there are only around 300 species of pouched marsupials, and a mere five monotremes, archaic holdovers like the platypus that still reproduce by laying eggs.

MAMMALS ON PARADE

The ancient mammals were a weird bunch. Here are some of the strangest ones that scurried, stalked and clambered their way across ancient Earth, millions of years ago



Morganucodon
(Triassic, around 205 million years ago)
One of the very first mammals, living alongside some of the first dinosaurs. The size of a mouse, it had all of the classic features of mammals: hair, large brains (compared to reptiles), specialised teeth (incisors, canines, premolars, molars), and hyper-sensitive ears.

Repenomamus
(Cretaceous, around 125 million years ago)
About the size of a badger, it was one of the largest mammals that lived with dinosaurs. One fossil was found with baby dinosaur bones in its stomach, a last meal that inverts the classic story: some dinosaurs would have actually feared mammals.

Cimolestes
(Cretaceous, around 66 million years ago)
A scurrier that looked like a shrew, this anonymous mammal was either a very primitive placental or a close relative of the group. It is emblematic of the types of mammals living with the last dinosaurs, right before the asteroid hit.

Wortmania
(Palaeocene, around 65.6 million years ago)
A taeniodont, one of the groups of 'archaic' placentals that took over from the dinosaurs. It was a gargoyle-like digger, which used its massive, clawed forearms to rip through dirt. Its huge jaws and enlarged canines allowed it to eat tubers and other tough foods.

Periptychus
(Palaeocene, around 63 million years ago)
A condylarth, a member of a nebulous group of plant-eaters and omnivores with sturdy builds and hooves on their feet. There have been hundreds of 'condylarth' species described, but these have been hard to classify. Recent evidence indicates some of them may be early relatives of horses and cattle.

Eoconodon
(Palaeocene, around 65.6 million years ago)
The terrors of the early Palaeocene, this triisodontid was the top predator in its ecosystem, and preyed on condylarths and taeniodonts. Living soon after the extinction, it took over top predator niches from carnivorous dinosaurs like raptors.

Pantolambda
(Palaeocene, around 64 million years ago)
An archaic placental called a pantodont, it was among the first large plant-eating mammals in Earth's history. About the size of a small cow, it had a barrel-shaped chest and enlarged hands and feet.

Among modern-day placentals are bats, whales, elephants, dogs, cats, monkeys and humans. Our roots go back to that manic time after the asteroid hit, when new ecosystems were emerging from the chaos.

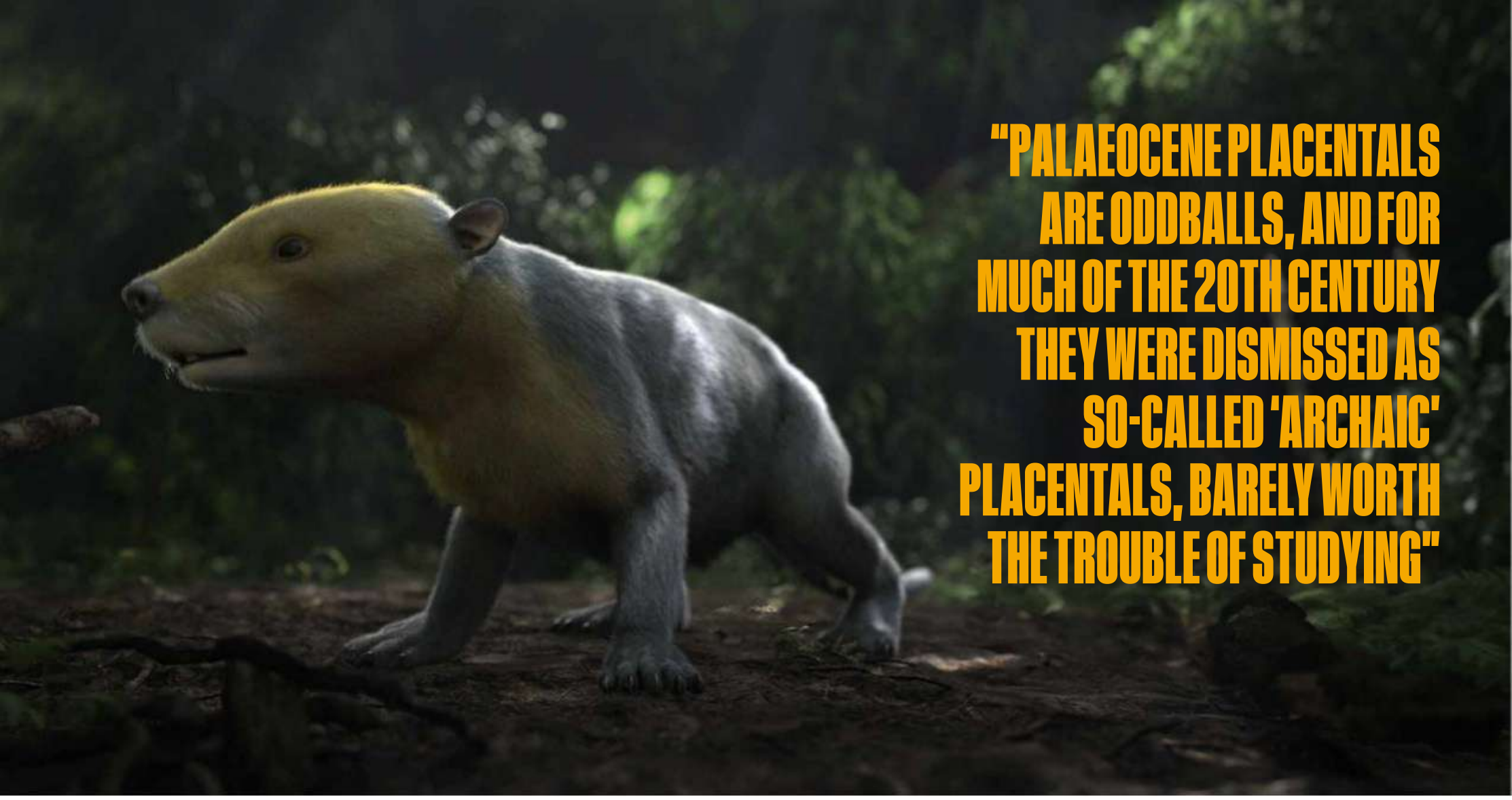
As the wildfires burnt out, and the Sun emerged from the soot clouds and the global warming abated, many of the mammals that started to multiply in the ensuing Palaeocene (66-56 million years ago) were placentals. Not only did they diversify, but they got much larger, as they filled the ecological vacuum left by the dinosaurs. Within a few hundred thousand years of the asteroid, there were placentals the size of pigs, and within a couple of million years, some were as big as cows. Many of the best fossils of these pioneering placentals come from New Mexico, where Dr Thomas Williamson has worked for decades. Over the last 10 years, my students and I have joined his team and collected a bounty of teeth, jaws, and skeletons of those placentals living in the first few million years after the asteroid impact.

These first placentals, to put it bluntly, were weird. Ever since they were first discovered in the 1870s and 1880s during land surveys of the American west, their fossils have confounded scientists. Their skeletons are odd: their bones are stocky, their posture plodding, and their bodies would have been cloaked in thick muscles. They cannot be easily pigeonholed into the modern placental groups; in other words, the Palaeocene placentals are not obviously bats or dogs or horses. These animals are oddballs, and for much of the 20th Century they were dismissed as so-called 'archaic' placentals, barely worth the trouble of studying. What were their relationships to today's placentals, and how did they move, eat, and grow? We have known very little, until now.

LEFT TOP Dr Ian Miller's studies have helped us find out more about early placentals

LEFT MIDDLE Dr Tyler Lyson splits open a concretion to reveal a vertebrate skull fossil

LEFT BOTTOM An overhead shot of prepared mammal skull fossils retrieved from Corral Bluffs in Colorado



"PALAEOCENE PLACENTALS ARE ODDBALLS, AND FOR MUCH OF THE 20TH CENTURY THEY WERE DISMISSED AS SO-CALLED 'ARCHAIC' PLACENTALS, BARELY WORTH THE TROUBLE OF STUDYING"

Two breakthroughs have helped us to, finally, unmask these placental pioneers. First are the many new fossil discoveries by Williamson and his teams in New Mexico, plus other remarkable new finds by Dr Tyler Lyson and Dr Ian Miller and their teams in Colorado, along with other discoveries across the world. Second are new technologies that help us study these fossils, and understand what they were like as real animals.

The roster of 'archaic' placentals includes animals like pantodonts, condylarths, and taeniodonts. Untangling their genealogical relationships is tricky, but my team at the University of Edinburgh is working on it now. Our initial results are encouraging: some of these 'archaic' placentals, like taeniodonts, might be among the most primitive placentals on the family tree. Others, like some of the condylarths, share anatomical features with today's hoofed mammals and are probably early cousins of horses and cattle. Other Palaeocene species, like *Purgatorius*, seem to be on the primate line: ancestors of monkeys and apes, and us.

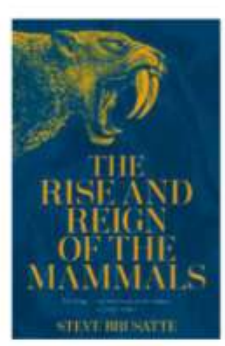
No matter their exact placement on the family tree, these placentals developed novel features and behaviours, which allowed them to adapt to the Palaeocene world and establish a new Age of Mammals. Many members of my lab are leading research on this subject. By making thin slices of bones and teeth to examine under the microscope, Dr Greg Funston can discern the growth trajectories of these mammals, and can tell that some of them nurtured babies in their wombs for around seven months – much longer than non-placental mammals. Such prolonged development unlocked a nifty trick: larger offspring could more easily grow into larger adults, which probably enabled these mammals to balloon in size so soon after the dinosaurs disappeared.

Palaeocene 'archaic' placentals got so big so fast that their brains could not keep pace. This is the shocking revelation of a project by Dr Ornella Bertrand, who used computed tomography (CT) scans of fossil skulls to show that relative brain size – the ratio of brain volume to body mass – actually decreased after the asteroid. It might seem counterintuitive that the mammals that survived the extinction and thrived afterwards did not do so with keen intelligence. Yet, by keeping their brains smaller, they may have been able to invest more resources in growing their bodies, and diversifying their diets and locomotion. As another recent study by Dr Sarah Shelley shows, the 'archaic' placentals were capable of many types of movement – including burrowing, trotting, and climbing – despite their superficially 'generalised' stocky skeletons.

ABOVE The ancient mammal *Taeniolabis*

PLACENTALS MODERNISE

Over time, as the Palaeocene turned into the Eocene (56-34 million years ago), the new mammal-dominated ecosystems stabilised, and even got a little crowded. Meanwhile, the global thermostat ran hot, and a sudden global warming event, called the Palaeocene-Eocene Thermal Maximum, made the temperatures boil even further. In the face of yet another burst of environmental change, mammals proved resilient again. Few species went extinct, but rather, the 'archaic' placentals gave rise to their modern descendants – the first true primates, horses, and cattle – which swept across much of the globe. As these new placentals swung from the trees, dipped their toes in the water, and turned arms to wings, the shape of today's mammalian menagerie came into focus. **SF**



by **PROF STEVE BRUSATTE**
(@SteveBrusatte)
Steve is a professor and palaeontologist at the University of Edinburgh and the author of the new book The Rise And Reign Of The Mammals *(£20, Picador), a 325-million-year odyssey of mammalian evolution and the people who study mammal fossils.*

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Q&A

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... WHAT IS AN AMBIVERT?
... DOES EATING SPICY FOOD GIVE ME ACID REFLUX?
... WHAT IS PHANTOM VIBRATION SYNDROME?
... WHAT IS A SQUALL LINE?
... DOES MASSAGE WORK?
... HOW DOES A QUEEN BEE GET TO BE QUEEN?
... WHAT IS VERTICAL FARMING?
... WHAT IS SLEEP INERTIA?
... WHY DO DOGS LOOK LIKE THEIR OWNERS?
... WHY ARE BISCUITS SO ADDICTIVE?
... HOW DOES FOG FORM?

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QUESTION OF THE MONTH

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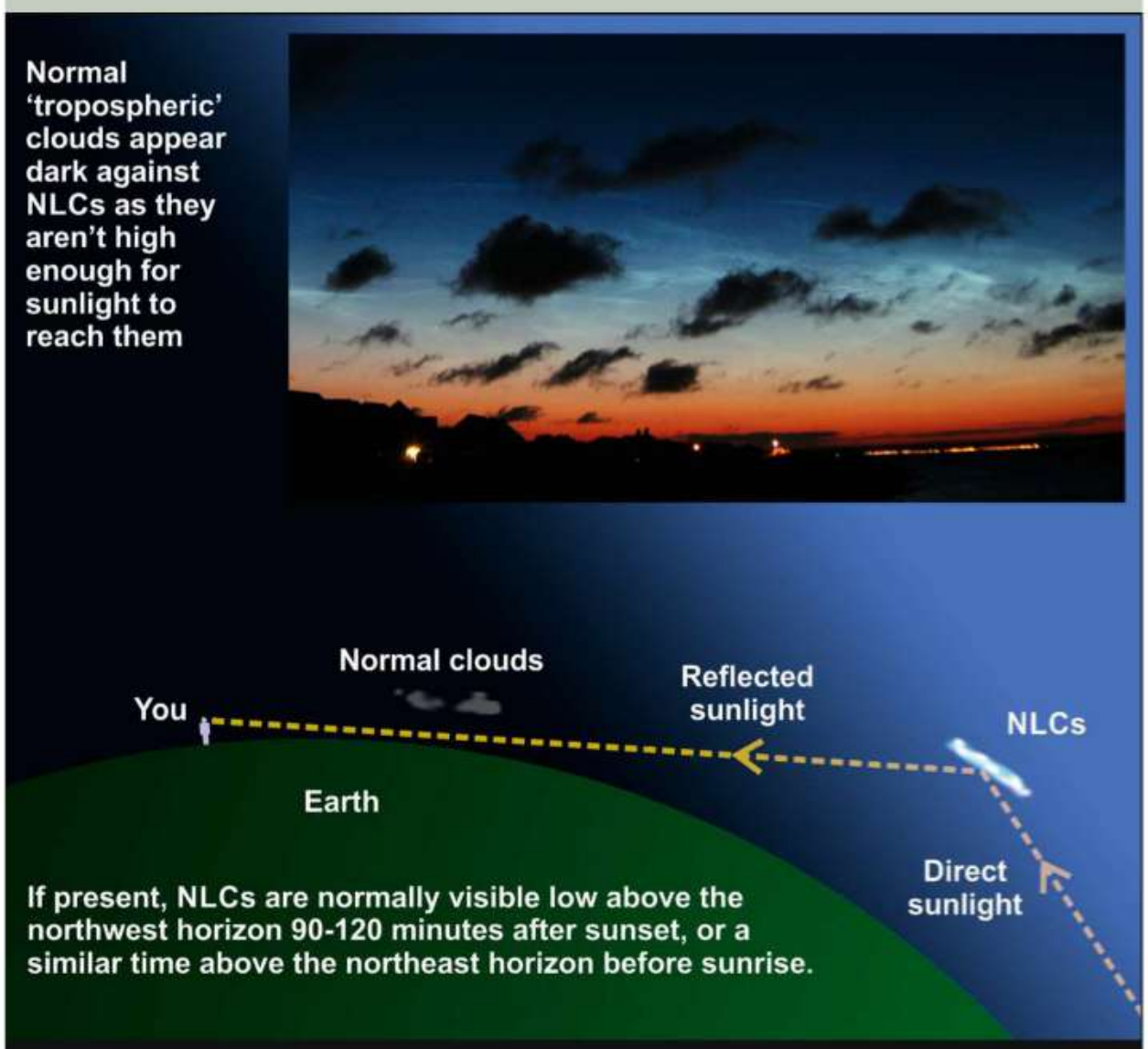
CHRIS HAMER, LONDON

IF YOU WERE SWALLOWED WHOLE BY A VERY LARGE ANIMAL, HOW LONG WOULD YOU REMAIN ALIVE FOR AND WHAT WOULD YOU DIE OF?

In 2014, Discovery Channel aired a controversial documentary where the presenter attempted to get eaten alive by a six-metre anaconda, while wearing a protective suit. The snake attacked, but the stunt was halted before the man was swallowed, since he was in danger of having his arm broken by the anaconda's constricting coils. Anacondas will always suffocate their prey to death first before swallowing it, since it would be dangerous to have a live deer or tapir kicking in the stomach. Even when their prey is dead, swallowing something this large is quite risky for these snakes and they can sometimes die in the attempt. Other large animals such as crocodiles would certainly bite you into smaller chunks first. A large whale could theoretically manage it, although blue whales have a surprisingly narrow oesophagus and can't swallow anything larger than a melon. In reality, the only animal large enough to swallow you whole without killing you first, or in the process, is a sperm whale. But even if you manage to dodge its teeth, your death certificate would still say 'chomped to death'. Sperm whales use their teeth to catch and hold large prey, but they don't chew with their mouths. This job is delegated to the first of their four stomach chambers. The stomach walls are very thick and muscular, to grind up fish and giant squid, before they pass to the other chambers and digest in the gastric juices. There is no breathable air in a whale's stomach, so you would have at most three minutes before you asphyxiated. But before that you would have been crushed to death, in a scene reminiscent of the trash compactor sequence of *Star Wars: Episode IV.* ***LV***

ILLUSTRATION: DANIEL BRIGHT

ASTRONOMY FOR BEGINNERS


Normal 'tropospheric' clouds appear dark against NLCs as they aren't high enough for sunlight to reach them
Normal clouds
Reflected sunlight
You
NLCs
Earth
Direct sunlight
If present, NLCs are normally visible low above the northwest horizon 90-120 minutes after sunset, or a similar time above the northeast horizon before sunrise.

NOCTILUCENT CLOUDS (NLCs)

WHEN: LATE MAY-EARLY AUGUST

Night darkness is in short supply during the middle of the year, as sunset is late in the day and sunrise early. In addition, the Sun's position below the northern horizon in the middle of the night means much of the UK never sees proper darkness at all. Although this is a challenging time for stargazing, there is another phenomenon that can only be seen at this time of year.

Noctilucent clouds (NLCs) are ice-sheet clouds forming at an altitude of around 80km (50 miles) in a thin region within the mesosphere. The mesosphere is a defined layer of Earth's atmosphere, extending from an altitude of 50-120km (30-75 miles). During the northern hemisphere's summer, the temperature of the mesosphere drops and any water vapour present becomes supercooled. If small particles pass through the supercooled vapour, tiny ice crystals form, creating NLCs. If you're wondering what the astronomical connection is here, the natural supply of seeding particles is the dust left after a meteor vaporises in the atmosphere.

If present, NLCs can normally be seen low above the northwest horizon between 90 and 120 minutes after sunset, or low above the northeast horizon before dawn. Extensive displays may appear low in the northwest, track through north and end low in the northeast.

Despite the Sun having set for us on the ground, from the altitude of the NLC sheet the Sun is still up. Consequently, the sheet reflects sunlight and, from our perspective at least, appears to shine at night. This is where they get their name: noctilucent means 'night shining'.

NLCs can be very beautiful, glowing against the deep twilight sky with a vibrant electric blue colour and often showing fine, net-like structures. ***PL***

FRANKIE BROWN, LONDON

WHAT IS AN AMBIVERT?

Love partying and adventure? You're probably an extravert. Prefer quiet time to read and reflect? You're more likely an introvert. If you're somewhere in the middle and like a mix of these experiences, you might be an ambivert. First proposed by the US psychologist Edmund Smith Conklin in 1923, the idea that some of us are ambiverts fell out of favour in personality psychology, which today sees the main personality traits (including extraversion) as dimensions rather than types.

However, the concept captured the popular imagination – and inspired a thousand online quizzes – in 2013 after another US psychologist, Adam Grant, published research suggesting that people with a mix of introverted and extraverted tendencies have an adaptable interpersonal style that helps them to excel in sales. ***CJ***

ANDY MANN, BIRMINGHAM

WHAT IS PHANTOM VIBRATION SYNDROME?

Ever felt your phone buzz in your pocket, then pulled it out to find no text, no call, no notification? You might be experiencing 'phantom vibration syndrome'– and you're not alone. According to one study, 9 out of 10 undergraduates said they had experienced the phenomenon in the last week or month.

Scientists aren't exactly sure why these tactile hallucinations happen to so many of us. One leading theory is that our excessive smartphone use, and our creeping sense that we should be constantly available, have conditioned our brains to overinterpret sensations such as clothing moving against our skin. On the plus side, most people don't find the phantom signals bothersome. ***CP***

GETTY IMAGES X2, ALAMY ILLUSTRATIONS: PETE LAWRENCE, DANIEL BRIGHT

KATE FRANKLIN, EXMOUTH

DOES EATING SPICY FOOD GIVE ME ACID REFLUX?

Acid reflux occurs when the stomach's contents shoots back up into the oesophagus, which can cause an unpleasant burning sensation. People with frequent symptoms of acid reflux and heartburn may be diagnosed with gastro-oesophageal reflux disease (GORD). The highest levels of GORD are reported in Europe and the US, with the lowest in Asia.

Although many people report that spicy foods give them acid reflux, the scientific data on this is by no means definitive. The key suspect is thought to be a substance called capsaicin, which gives chillies their heat. Capsaicin activates so-called TRPV1 receptors in the oesophagus to produce a burning sensation.

One small Mexican study found that capsaicin triggered symptoms such as heartburn and chest pain in 28 of 31 people with diagnosed GORD and in 6 out of 17 'healthy' people. Meanwhile, a US study found that adding capsaicin to food brought on 'peak heartburn' sooner after eating. In 2020, Thai medics reported that GORD patients experienced more severe heartburn after eating a meal containing chilli, although it did not affect healthy people.

Acid reflux and GORD are triggered by a number of factors, especially obesity. Fatty foods also aggravate symptoms because they take longer to pass through the stomach, increasing pressure on the valve that leads to the oesophagus.

A South Korean study found that hot, spicy stews, noodles and fried foods were regular heartburn offenders. The researchers point out that eating too quickly and continuing to eat after feeling full also exacerbates symptoms.

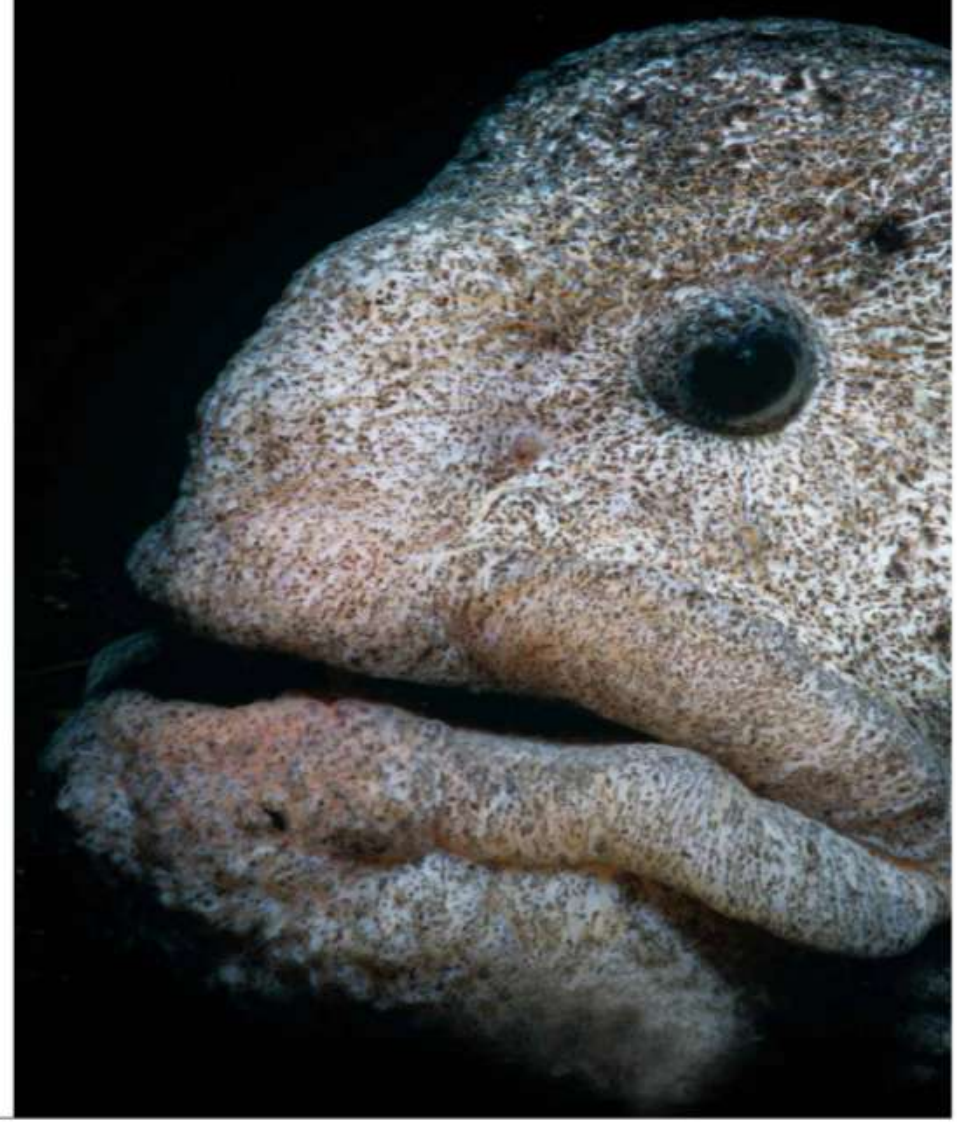
Interestingly, eating chilli regularly could be the best thing to do. A Taiwanese study found that although capsaicin increases heartburn if you eat it once, taking it regularly significantly reduces symptoms. At higher doses, capsaicin acts as a painkiller. Some people indeed report anecdotally that eating chilli or cayenne pepper regularly has cured their GORD symptoms. So maybe that's the answer. Extra chillies with everything! ***ED***

NATURE'S WEIRDEST ANIMALS...

WOLF EEL

Wolf eels are scary-looking fish, with crab-crunching teeth, powerful jaws and speckled, grey bodies that look like they've been sculpted from a block of granite. They can live for at least 20 years and are enormous, up to 2.4 metres long, although mostly they hide their tapering bodies in caves and crevices in rocky reefs with just their heads sticking out. Wolf eels are not actually eels, but are members of a fish family known as wolf fish or sea wolves. They live in the cold waters of the North Pacific, from California to the Sea of Japan, down to around 200 metres underwater.

They begin life as small, transparent larvae drifting through the seas, then develop into bright orange juveniles. These young fish swim through open waters until they're ready to settle down. Then they search for a suitable cave and a partner. A male and female tend their clutches of eggs, up to 10,000 at a time, protectively wrapping their bodies around them and aerating them with oxygen-rich water. The eggs take four months to hatch and all the while the male and female take turns to leave the cave and hunt. Once the baby eels have hatched and left, the parents set about raising their next clutch. Wolf eels mate for life. ***HS***



ADAM MARSH, VIA EMAIL

WHAT IS A SQUALL LINE?

A squall line is a fast-moving system of thunderstorms in a long, narrow line formation. They can stretch for hundreds of miles (typically arranged north-south) but are usually less than 32km (20 miles) wide. As they sweep across the landscape, they deliver a short, violent burst of weather that can include dangerous straight-line winds, lightning, hail, and torrential rain.

Squall lines tend to form in the mid-latitudes, where they move from west to east, or the tropics where they move east to west. They are most common in the US, east of the Rocky Mountains, especially during the spring.

Squall lines are usually seen along, or ahead of, the leading edge of a cold front. As it advances, the cold, dense air forces warmer, moister air in its path to rise. As the warm air rises, it cools, and the moisture it contains condenses into a cloud. Meanwhile, a downdraught of cold air from the top of the storm cloud rushes in to take its place, slamming into the ground and spreading out in all directions. Ahead of the storm, this frigid 'gust front' intensifies the lifting effect and causes wind shear at the boundary of the two air masses, and can generate an ominous-looking shelf cloud. When the winds propelling a squall line forwards are strongest at the midpoint of the line, a feature called a 'bow-echo' can develop. On a radar image, this appears as a band of heavy rain shaped like an archer's bow. Occasionally, tornadoes spring up at the trailing tips of the bow. At their most extreme, bow echoes can become self-sustaining storms known as derechos, which maintain their structure for several hours, produce gusts as strong as a Category 1 hurricane (120km/h), and inflict wind damage along a path of 400km (250 miles) or more. ***CP***

CROWDSCIENCE

Every week on BBC World Service, *CrowdScience* answers listeners' questions on life, Earth and the Universe. Tune in every Friday evening on BBC World Service, or catch up online at **bbcworldservice.com/crowdscience**

DOES MASSAGE WORK?

Historical artefacts show that massage has been practised for at least 5,000 years, but people have probably appreciated a nice back or foot rub for much longer than that! Many people find massage an enjoyable experience, but is it also medically beneficial?

You might have heard that massage can reduce pain and muscle soreness, relieve muscle knots, flush out toxins, boost the immune system, reduce stress, and prevent depression.

Scientists have since confirmed many of these claims, while others have been disproved. For example, research has found that massage can reduce pain intensity and relieve muscle tension, lower heart rate and blood pressure, and improve the symptoms of anxiety, fibromyalgia and osteoarthritis.

Massage can aid muscle recovery after exercise. A 2008 study found that massaged muscles had recovered 60 per cent of their strength after four days, compared to just 14 per cent for muscles that were only rested. The massaged muscles had fewer damaged fibres and signs of inflammation, which may explain why they recovered faster.

Exactly what massage does at a cellular level is not fully understood, but researchers at McMaster University in Ontario, Canada found that post-exercise massage stimulated the production of energy-generating structures, called mitochondria, and reduced inflammatory proteins. On the other hand, they found no evidence for one claim about massage: that it works by clearing out excess lactic acid. *CA*

GETTY IMAGES X2, ALAMY ILLUSTRATIONS: DANIEL BRIGHT

MARY REYNOLDS, PLYMOUTH

HOW DOES A QUEEN BEE GET TO BE A QUEEN?

The queen bee is mother to all members of the hive and is the only bee in the colony to lay fertilised eggs. Her pheromones are so powerful that they bond the colony together as a social unit, and her absence is very quickly noticed.

1. Special cells – called queen cups – are cleaned and enlarged by workers.

2. When the current queen is nearing the end of her reproductive cycle, she'll start to lay eggs in the queen cups. If the current queen is dead, missing, or unable to lay fertilised eggs, worker bees will urgently choose a suitable larva already in the comb to become the next queen.

3. After three days, a larva hatches from the egg.

4. The young larva is fed a special food called royal jelly, a sweet protein-rich substance secreted from the hypopharyngeal glands of nurse bees.

5. The larva grows very quickly, and after around seven days, the worker bees seal the top of the queen cell with wax.

6. Inside the sealed queen cell, the larva spins a cocoon.

7. The larva metamorphoses into a pupa.

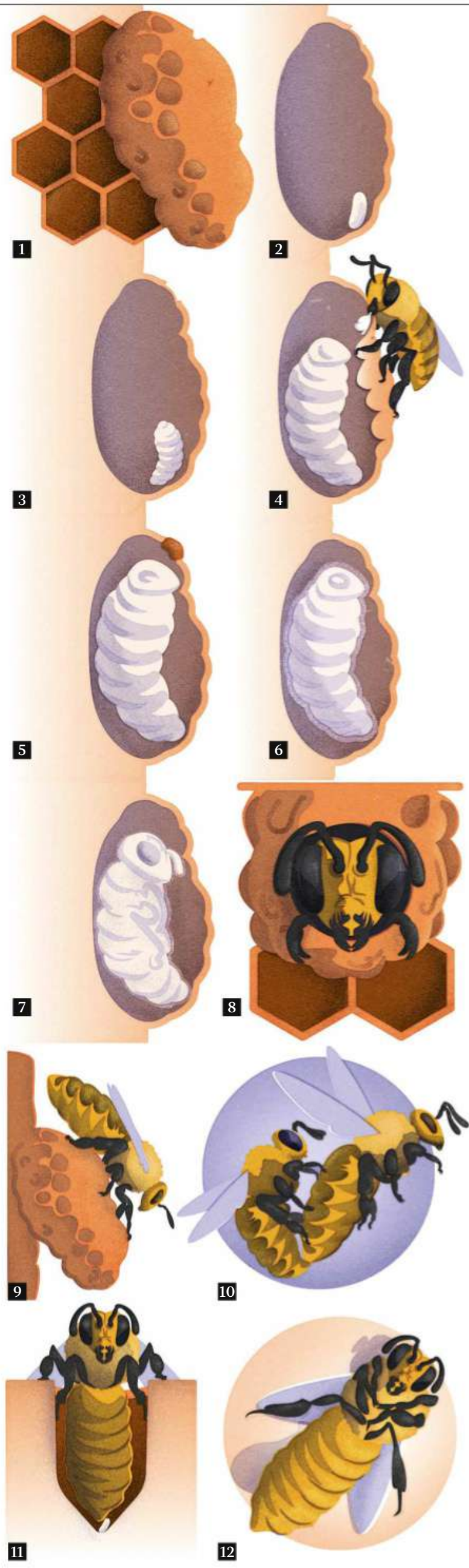
8. After another eight days or so, a fully-formed queen chews through the wax cap and emerges.

9. The new queen destroys potential rivals that may be developing in other cells.

10. After a few days, she mates with drones in the air.

11. Once her sperm-storing organ is full, she will return to the hive to lay as many as 3,000 eggs per day while worker bees keep her well-fed and clean.

12. Queens live for around 1-2 years. When she dies, or reaches the end of her reproductive life, the cycle starts again.



LAURA RAYNER, VIA EMAIL

WHY DO DOGS LOOK LIKE THEIR OWNERS?

Studies that ask participants to match dogs with their owners reveal that pooches do indeed often resemble their people. One reason could be that familiarity breeds content. We love our human family and so are drawn to dogs with similar features, but the phenomenon could also be a spin-off from the way we have evolved to choose our human mates. People who select a physically similar partner may inadvertently be selecting for genetic compatibility, and although our canine relationships are purely platonic, we may subliminally apply the same standards. ***HP***

AVA EDWARDS, VIA EMAIL

WHY ARE BISCUITS SO ADDICTIVE?

Sweet, fatty biscuits trigger our brain's reward circuit, flooding it with dopamine and making us feel good. We also tend to find crunchy foods satisfying to eat, from a sensory perspective. So, it's easy to see why we soon reach for another biscuit seconds after the first. But that's not to say that biscuits are actually physically addictive. A bare biscuit tin may deliver disappointment but does not cause withdrawal symptoms.

The concept of food addiction remains controversial after many years of debate in scientific journals. However, a German study on mice in 2021 found that females were more likely to consume excessive amounts of sugar than males. Do women eat more biscuits than men? We will probably never know. ***ED***

DEAR DOCTOR...

HEALTH QUESTIONS DEALT WITH BY *SCIENCE FOCUS* EXPERTS

I ALWAYS FIND THINGS TO DO LATE AT NIGHT AND IT'S STOPPING ME FROM SLEEPING. HELP!

Life is busy and there are usually multiple things that we could be doing at any particular time. In this case, perhaps chipping away at an endless to-do list is leading to a late bedtime. An alternative possibility is that a hectic day can result in the desire to take time out for ourselves once the working day has finished. Perhaps we call friends or catch up on TV shows rather than sleep. This latter possibility has been referred to as 'revenge bedtime procrastination', which stems from a Chinese saying reflecting an absence of free time due to our hectic and stressful working lives. This is not a phrase used widely within scientific literature – although there are studies focusing on bedtime procrastination more generally – which suggests that this is associated with poor self-regulation and missing out on sleep. Given this, it might be worthwhile considering different techniques that can be used to reduce procrastination. A review of the literature highlighted different interventions for reducing procrastination more generally, including those focusing on developing self-regulation (for example, setting a bedtime and developing time-management skills) and cognitive-behavioural techniques (challenging those thought patterns that could be maintaining the procrastination). These techniques now need to be further tailored specifically for sleep procrastination to be most effective for those who are missing out on their Zzzs. *AG*

RICH FRENCH, LONDON

WHAT IS VERTICAL FARMING?

It's a way of taking the controlled environment of a modern commercial greenhouse to the literal next level. By stacking plants vertically on shelves or tall pillars, vertical farming allows 10 times the yield for a given land area. Plants are grown in completely enclosed conditions, with LED lights replacing sunshine, and closed-loop recycling of water. There is no need for pesticides, since the indoor space is already free of bugs, and plants can be grown in such clean conditions that there is no need to wash them before eating. A vertical farm can fit the equivalent of 280 hectares (700 acres) of farmland in a building the size of a large supermarket, and by manipulating the artificial day length and season, it can harvest crops all year round.

Intensive indoor agriculture suffers from high start-up costs and energy bills, but recent advances in increased efficiency and lowered manufacturing costs of LEDs have begun to make vertical farms more cost-effective. It currently only makes sense for certain crops though. Salad leaves and strawberries are small plants with large profit margins, but cereal crops – like wheat and corn – are too tall to stack efficiently and have a much lower value per tonne. A loaf of bread made from vertically farmed wheat would cost around £18, just for the electricity to power the LED lighting, according to a study at Cornell University. Solar panels on the roof and walls of the building are not enough to make vertical farms self-sufficient. But indoor agriculture allows farming to be integrated directly into cities, reducing food miles. It is more efficient to transport electricity from rural solar farms to a city and grow the food close to where people live. This closed-loop growing cycle could be much less polluting to the environment too, and may even be the answer to supplying human settlements on the Moon or Mars. ***LV***

KAYLEIGH SUMMERS, DORSET

HOW IS FOG FORMED?

Fog consists of molecules of water vapour, suspended in the air as tiny droplets of water close to the surface of the Earth. It occurs when air saturated with water vapour is cooled suddenly, and there are several different ways this can happen.

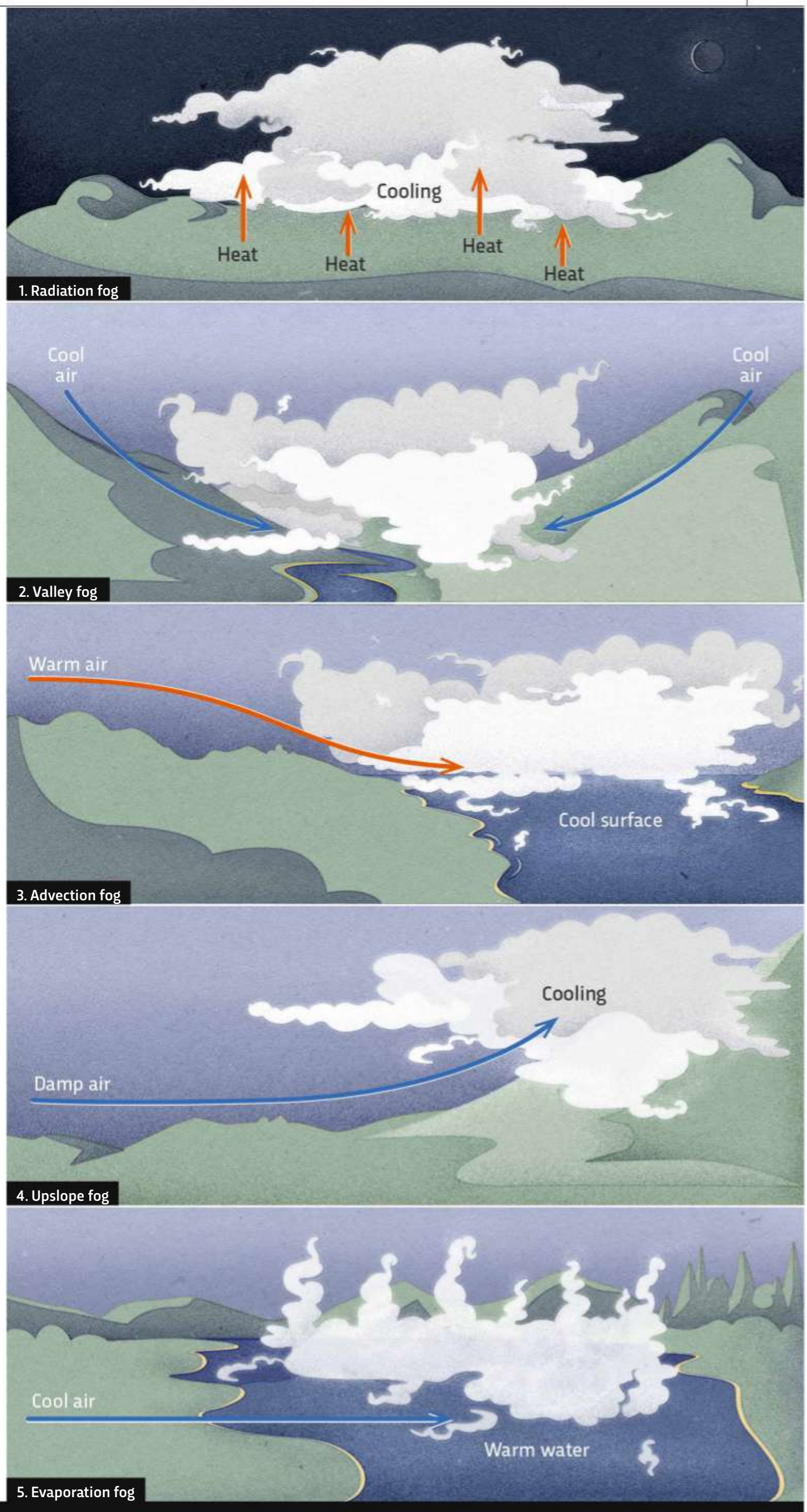
1. Radiation fog forms over land on calm, clear nights when heat absorbed by the Earth's surface during the day is radiated into the air. As the heat escapes upwards, air close to the surface is cooled until it reaches saturation. Cold air holds less water vapour than warm air, and the water vapour condenses into fog. Radiation fog will usually 'burn off' as the ground begins to warm again, but during winter months it can persist all day.

2. Valley fog usually forms in the lowest parts of a valley as cold, dense air settles and condenses, forming fog. It's confined by local topography, such as hills or mountains, and can persist for several days.

3. Advection fog forms when horizontal winds push warm, moist air over a cool surface, where it condenses into fog. It's common at sea, where warm, tropical air moves over cooler water. Advection fog can cover wide areas, and the Golden Gate Bridge in San Francisco Bay is often shrouded in advection fog.

4. Upslope fog forms when wind blows moist air up a slope, hill, or mountain, which cools as it rises. As it cools, the moisture condenses, and fog is formed as it continues to drift up the slope.

5. Evaporation fog forms as cold air passes over moist land, or warm water. When the warmer water evaporates into the low bands of air, it warms the air and causes it to rise. As this warm, moist air rises, it mixes with the colder air until its humidity reaches 100 per cent, and fog is formed.

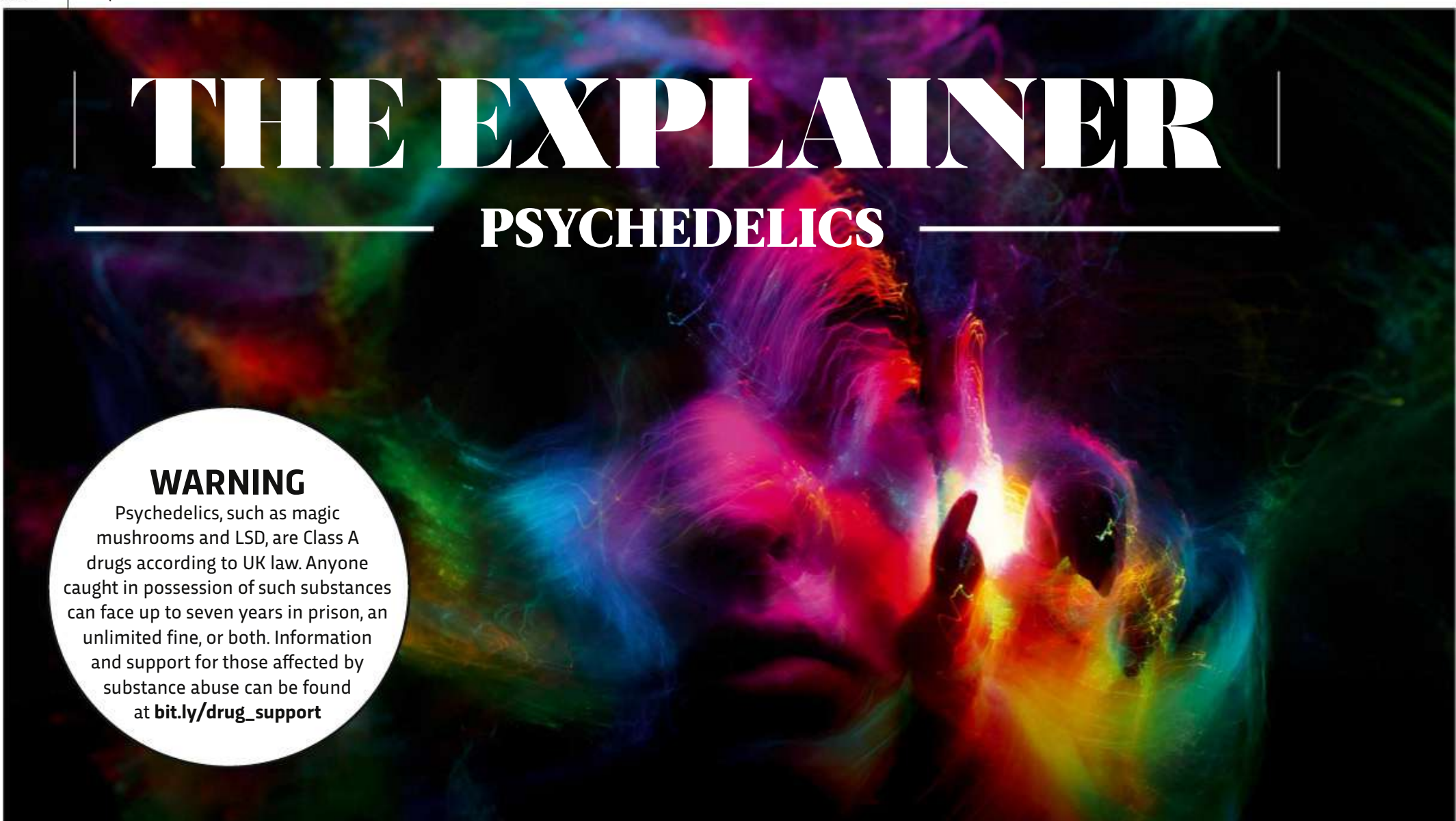


ILLUSTRATIONS: DAN BRIGHT

EMAIL YOUR QUESTIONS TO **QUESTIONS@SCIENCEFOCUS.COM**

THE EXPLAINER

PSYCHEDELICS



WARNING

Psychedelics, such as magic mushrooms and LSD, are Class A drugs according to UK law. Anyone caught in possession of such substances can face up to seven years in prison, an unlimited fine, or both. Information and support for those affected by substance abuse can be found at **bit.ly/drug_support**

WHAT ARE PSYCHEDELICS?

Psychedelics are psychoactive substances (ones which alter the brain's functioning) that are part of the 'hallucinogens' family. When ingested, they bring about an altered state of consciousness, involving temporary mental, visual and auditory changes, also known as a 'trip', or 'tripping'.

Humans have known about psychedelics for much of history. Many are naturally occurring, like psilocybin (the active compound found in magic mushrooms), or mescaline (found in the peyote cactus), and have been incorporated into tribal and spiritual rituals in many cultures.

However, largely due to a decades-long embargo on studying them, exactly how psychedelics work and what they can do for us remains mostly uncertain. However, recent advances in research have started to improve our understanding.

HOW DO THEY WORK?

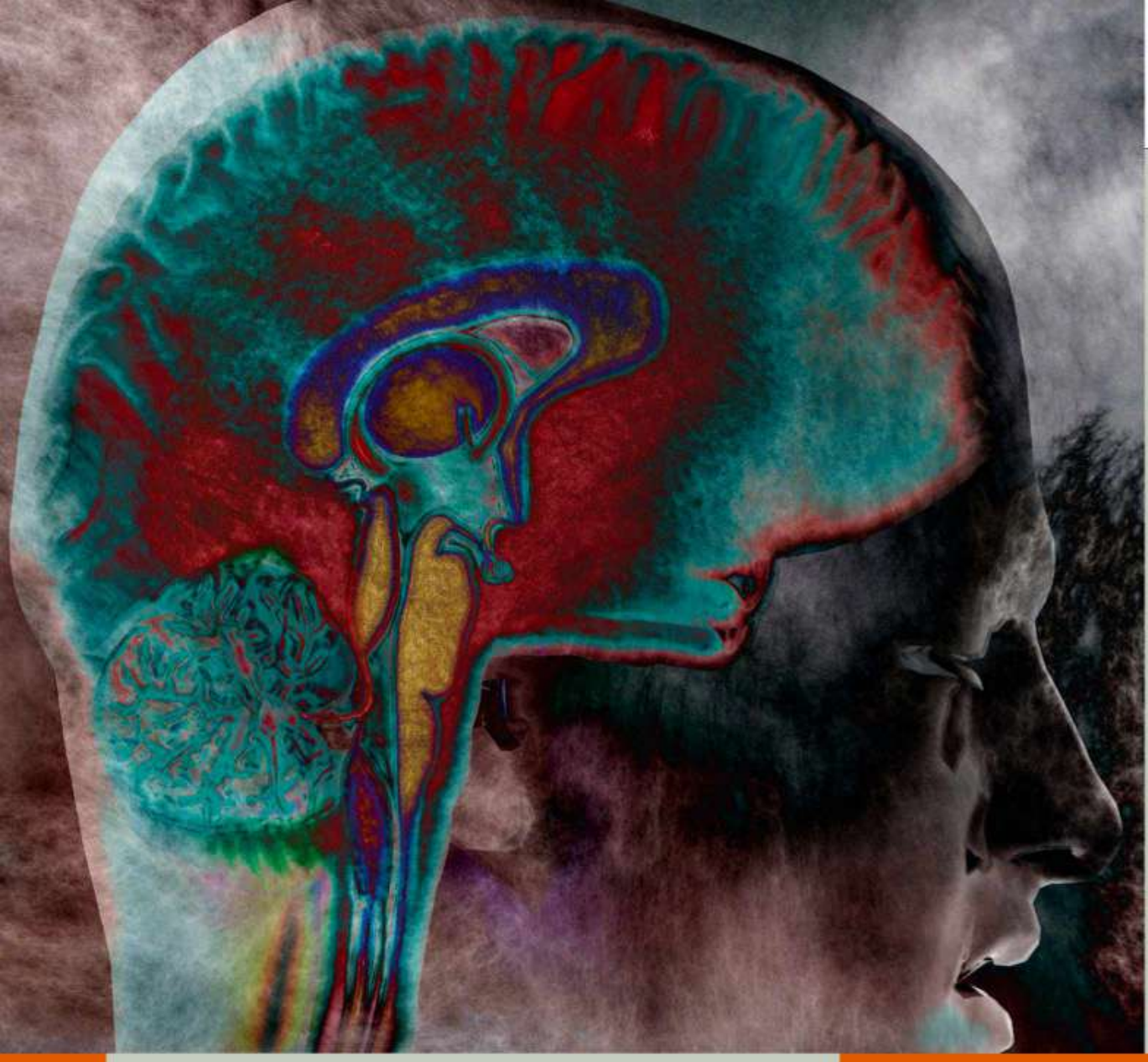
Most psychedelics increase activity in certain neurons that respond to the neurotransmitter serotonin. Serotonin has many varied functions in the human brain that are still being investigated. However, there is a growing evidence that suggests psychedelics act on the brain's default network. The default network seemingly provides a framework for our brain's activity, imposing order and structure on what's going on in our cortex. It keeps external neurological information, provided via our senses, distinct from internally generated activity, like thoughts, emotions and memory. Psychedelics seem to suppress the default network. One likely outcome is the relaxing of the separation of our senses, memories, thoughts and emotions, so they can influence each other more readily.

Artist's impression of LSD (blue) fitting in to the serotonin receptors (white ribbon)

Small 'microdoses' of LSD

HOW CAN THEY BE USED FOR MENTAL HEALTH TREATMENT?

When it comes to mental health problems, psychedelics may have therapeutic value, both in terms of range and efficacy. Studies thus far have been limited and small, but several have shown psychedelics are potentially an effective ingredient in the treatment of mood disorders like anxiety, depression, alcoholism, OCD, and even criminal behaviour.



ARE THERE SIDE EFFECTS?

Chemically altering your brain's workings is never something to be taken lightly. Still, psychedelics have low addictive properties, meaning you're unlikely to end up 'hooked' on them. Those with pre-existing vulnerabilities to psychosis can react badly to psychedelics, but even for 'typical' people, their mindset upon taking a psychedelic has significant effects on experience. This means it's possible to have a 'bad trip', resulting in low mood, anxiety and panic attacks. The potency of some psychedelics, particularly LSD, can mean side effects are more enduring, with reports of upsetting flashbacks occurring long after the original trip. Someone under the influence of a psychedelic also has a distorted perception of reality, meaning they can end up doing serious harm to themselves without even realising.

Psychedelic research in labs is carried out in highly controlled, safe environments, with experts on hand to minimise any potential risk.

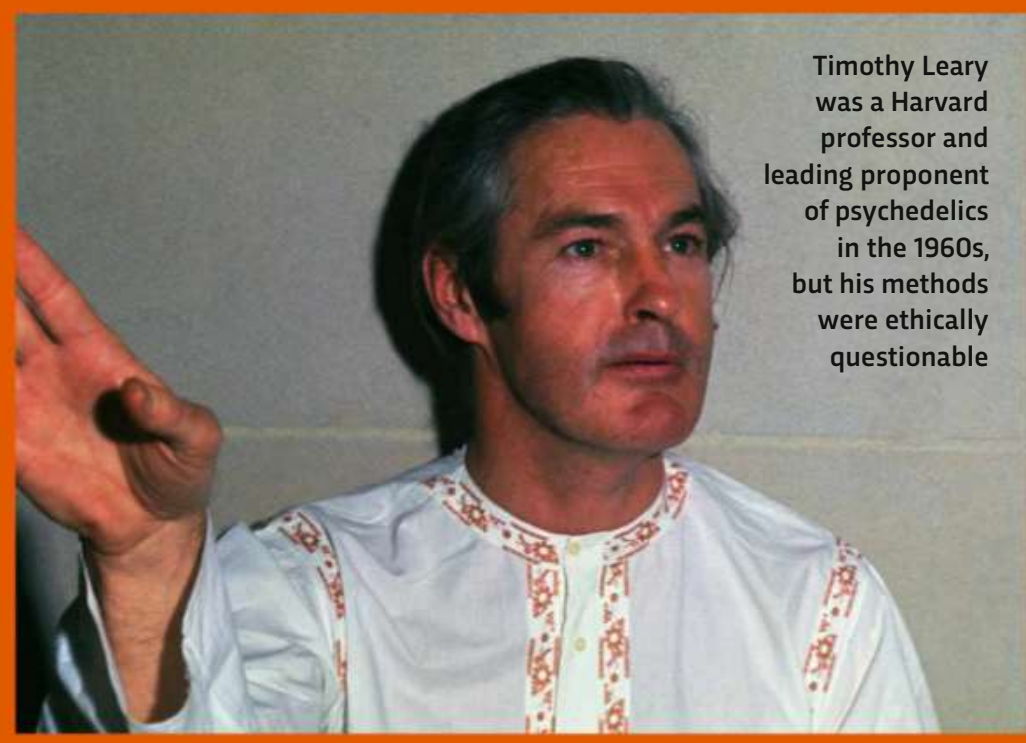
WHY ARE PSYCHEDELICS BEING USED TO TREAT SUCH A RANGE OF PROBLEMS?

Given how complex and uncertain the workings of psychedelics still are, there are many possible explanations. However, one likely answer is, as just described, the potent impact psychedelics have on the brain's default network.

Whether it's the stressed-out neurons that regulate mood becoming inflexible (depression), the reward pathways gradually distorting our thinking processes (addiction), or the inability to move on from intrusive or violent thoughts (OCD), one common aspect of mental health disorders is that they invariably involve a brain that has adapted to what it has experienced, but in unhelpful and disruptive ways.

Many mental health interventions, however they work, are ultimately striving to coax the brain to adopt a new, less-disruptive form. And this may be where psychedelics have the advantage.

By having such a powerful suppressive impact on the default network – thus reducing neurological boundaries, and allowing many novel stimulating links between the various brain regions – psychedelics may strike at the root of many mental health disorders, reconfiguring or overwhelming the unhelpful arrangement of neural connections that produce them, like waves demolishing sandcastles on a beach. However, they don't work on their own as a treatment: all studies so far have paired psychedelic drugs with weeks, if not, months of therapy.



Timothy Leary was a Harvard professor and leading proponent of psychedelics in the 1960s, but his methods were ethically questionable

WHY ARE THEY CONTROVERSIAL?

Despite being culturally fashionable from the 1950s to 1970s, psychedelics became controversial, largely due to dodgy research and unfortunate timing. Prominent researchers who were enthusiastic proponents of psychedelics ended up losing their jobs. Also, a good public image for psychedelics was hard to maintain when it was reported that the CIA had used it in experiments on mind control. Then there was research that suggested psychedelics may induce chromosomal defects. While later found to be inaccurate, it occurred just after the thalidomide scandal, which guaranteed a hostile reaction to any drug which had the possibility of causing birth defects. Richard Nixon's 'war on drugs' coming into play soon after was maybe the final nail in the coffin for the reputation and acceptance of psychedelics.

by **DR DEAN BURNETT**

Dean is a neuroscientist and author. His latest book is Psycho-Logical *(£9.99, Guardian Faber)*

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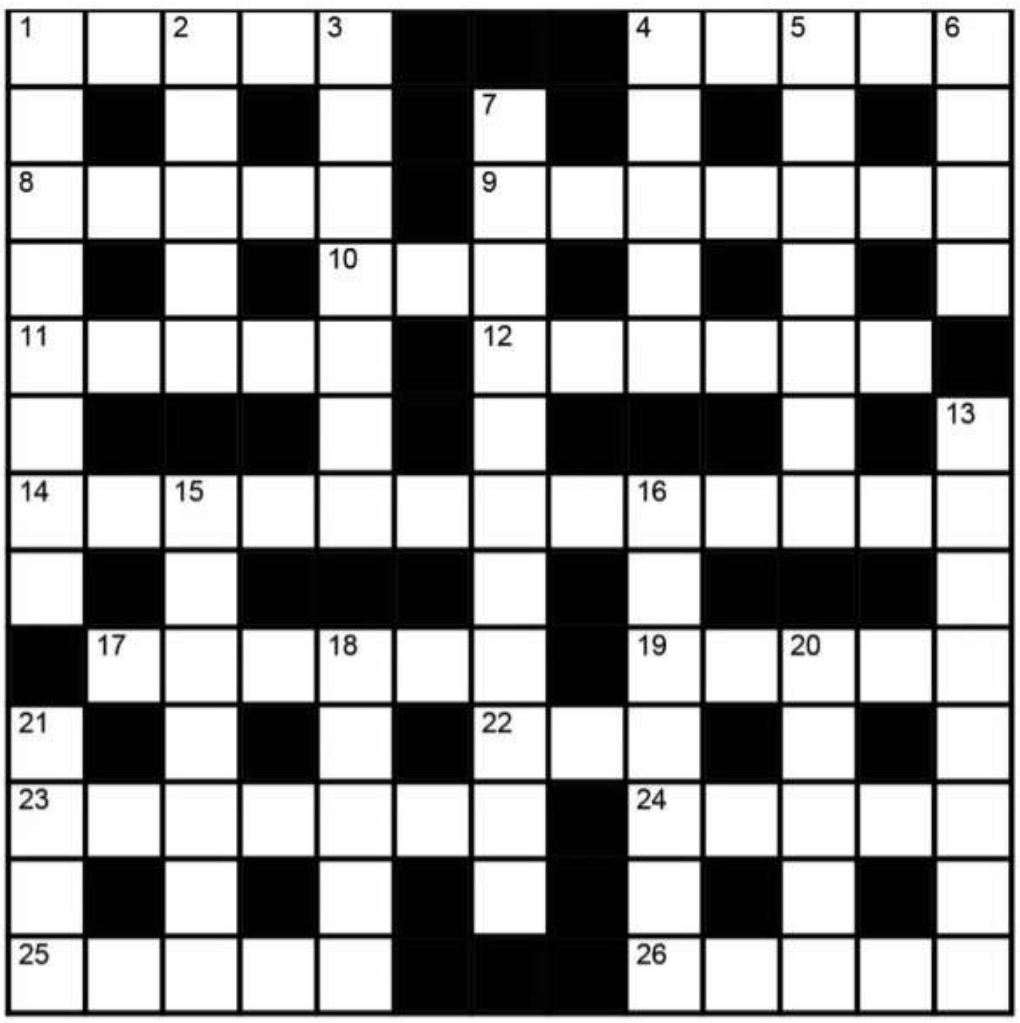
CROSSWORD

PENCILS AT THE READY!



ACROSS

1 Tricky question for model (5)
4 Reasonable to take king for an ascetic (5)
8 Fluid making her shake with hesitation (5)
9 Ministers' furniture (7)
10 Half-moon seen during March (3)
11 Dream about having some means of destruction (5)
12 Quote me in reverse – it makes you sick (6)
14 Response after series showing chemical process (5,8)
17 Country to plug and advertise sandwiches (6)
19 Look for water, initially, in some medicine (5)
22 Cat's check-up backfired (3)
23 Almost suggest returning gold at speed (7)
24 One laid out as an epic poem (5)
25 Exalted Egyptian figure wasted hours (5)
26 First couple of musicians finds Edward subdued (5)

DOWN

1 Language is equal to a weapon (8)
2 School's first squad showed old power (5)
3 Knock a karate expert fast (7)
4 Dishonest remark about indigestible material (5)
5 Raft back in identikit – no keel (3-4)
6 Damn vermin (4)
7 Pedal affected coracle rate (11)
13 Meant for fiancée (8)
15 Methodical, about to get swapped for article that's pointed (7)
16 Scoundrel has quiet word about one element (7)
18 Returned information on American drink (5)
20 Summons to get son inside joint (5)
21 Cut chat with husband (4)

JESSE WILD

ANSWERS

For the answers, visit **bit.ly/BBCFocusCW**
Please be aware the website address is case-sensitive.

NEXT ISSUE

INSIDE JET: THE WORLD'S BIGGEST FUSION EXPERIMENT

PLUS

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I spy some of the planet's weirdest peepers.

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What causes that irritating ringing in your ears, and is there a way to cure it?

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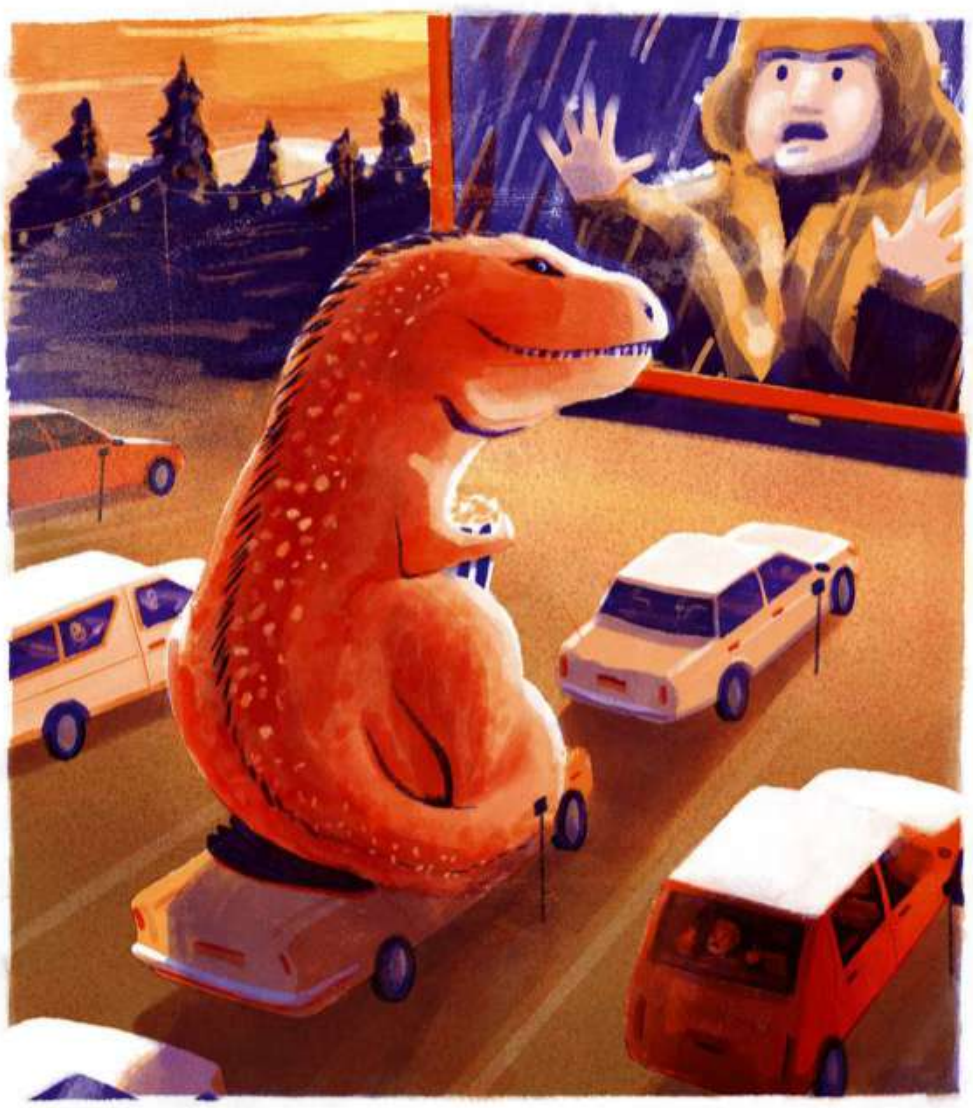
POPCORN SCIENCE

Could we live alongside dinosaurs?

In *Jurassic World Dominion*, the toothy ones have integrated into society...

by STEPHEN KELLY



The new *Jurassic World* movie envisions a time where dinosaurs are no longer every theme park's health and safety nightmare, but have instead started to reintegrate themselves as an ordinary part of our modern wildlife. *Velociraptors* stalk the woods like wolves. Men on horseback herd *Parasaurolophus* like cattle. A *Tyrannosaurus rex* disrupts a drive-in movie like... a bloody massive *Tyrannosaurus rex*. It's a premise that raises interesting questions. What impact would reintroducing dinosaurs into the wild have on our ecosystem, for example? And how would dinosaurs fare in a world so profoundly different to the one they originally lived in?

Prof Steve Brusatte, a palaeontologist at the University of Edinburgh and an advisor on *Jurassic World Dominion*, theorises that introducing, say, a *T. rex* into the British countryside would not be a great idea.

"There have been many cases where a predator is introduced to an ecosystem and wreaks havoc," he says. "It's happened when we brought rats or dogs to new islands, so just imagine something at the *T. rex*'s scale. It could certainly lead to some mammals going extinct."

It's not only carnivores that would disrupt the ecosystem, however. Giant herbivores like *Brontosaurus* could have a profound effect on crops and other plants that are important medicinally, says Brusatte. "Even the most conservative estimates say that sauropods would have eaten hundreds of pounds of leaves and stems every day."

But there is a question of whether dinosaurs could even survive long enough in our modern world to have any lasting impact at all. "Dinosaurs like *Brontosaurus*, *Diplodocus* and *Brachiosaurus* lived in the Jurassic," says Brusatte. "There were no fruits or flowers. Flowering plants were not even around until the early part of the Cretaceous. The vast majority of dinosaurs would never have seen a flower. Their diets were based on totally different types of plants. So whether they could even eat most of the food available to them today would be a really big question."

And then there's our climate. There is much debate over whether dinosaurs were primarily cold-blooded or warm-blooded, with recent studies (and Brusatte) concluding that they were likely a mix of both. Either way, the answer would have a huge effect on how easily dinosaurs could adapt to our environment.

"The global baseline for the temperature was much higher during the time of the dinosaurs," says Brusatte. "If they were fully warm-blooded, they could probably live in the kind of places that a lot of mammals could today. If they were more cold-blooded, that's different. We don't have crocodiles here in the UK for a reason. So if the dinosaurs did have more of a cold-blooded physiology, that's big swaths of the world today where they couldn't live."

However, Brusatte is optimistic that dinosaurs could adapt to whatever the natural world throws at them – apart from an asteroid. Instead, he suggests that their biggest danger would be co-existing with the apex predator of humanity.

"I think, in reality, we would just kill all the dinosaurs," he says. "I mean, if some mad scientist suddenly announced, 'hey, I've cloned 10,000 *T. rex* and they've all escaped,' the first thing we would do is hunt them down. Maybe we would co-exist with *Triceratops* or *Brontosaurus*, but big predatory dinosaurs? We have such deadly weapons and are really good at killing off things – I don't think we would co-exist." **SF**

VERDICT

Much as we might like to live alongside some dinosaur buddies, our aptitude for destroying wildlife and the world means it's probably not possible.

by **STEPHEN KELLY** *(@StephenPKelly)*
Stephen is a culture and science writer, specialising in television and film.

ILLUSTRATIONS: ADAM GALE MAIN ILLUSTRATION: SAM BREWSTER

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